VOLUME X. NUMBER 6

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

J. S. PLASKETT
Dominion Observatory
Ottawa

SIR FREDERICK STUPART
Director of the Meteorological
Service of Canada, Toronto

PUBLISHED MONTHLY

July-August, 1916

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. X. JULY-AUGUST, 1916. No. 6

W. F. King	*J. S. Plaskett*	267
The 72-Inch Reflecting Telescope	*J. S. Plaskett*	275
The Genesis of Planets	*Percival Lowell*	281
Great Meteoric Stream of February 9th, 1913	*W. F. Denning*	294
Orbit of the Spectroscopic Binary Boss 6142	*R. K. Young*	297
Location of Epicentres for 1914 and 1915	*Otto Klotz*	302
Magnetic Results, 1915	*Otto Klotz*	314
Meetings of the Society		
At Toronto	*W. E. W. J.*	321
At Ottawa	*E. A. H.*	323
Notes from the Meteorological Service		
Report of the Weather in Canada, April-May	*R. F. S.*	330
Magnetic Observations, March-April	*W. E. W. J.*	333
Earthquake Records at Toronto and Victoria, B.C., March-April-May	*J. Y.*	336
Astronomical Notes		
Recently Elected Honorary Fellows		338
Adams Spectroscopic Method, Measuring Stellar Distance		338
Comet 1916*a* (Neujmin)		340
Relative Velocities within Planetary Nebulæ		340
Researches on Solar Vortices	*J. R. C.*	341
Notes and Queries		
Close Conjunctions of Venus and Jupiter		342
Honor for Dr. Klotz		343
Another 'Runaway' Star	*C. A. C.*	343

Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the *Journal* is included in membership fee.

Anyone wishing to purchase a telescope may correspond with the Secretary, Toronto.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

OFFICERS FOR 1916

President—ALBERT D. WATSON, M.D.
First Vice-President—ALLAN F. MILLER.
Second Vice-President—WM. BRUCE, J.P.
Secretary—J. R. COLLINS. *Treasurer*—CHAS. P. SPARLING.
Recorder—W. E. W. JACKSON, M.A. *Librarian*—PROFESSOR C. A. CHANT.
Curator—ROBERT S. DUNCAN.

Council—The above Officers, and the following members:—Rev. I. J. KAVANAGH, M.A., D.Sc., S.J., Montreal; OTTO KLOTZ, LL.D., D.Sc., F.R.A.S., F.R.A.S.C., Ottawa; Rev. Dr. MARSH, F.R.A.S., Holstein; Sir JOSEPH POPE, K.C.M.G., Ottawa; STUART STRATHY, Toronto; Dr. W. M. WUNDER, Toronto; and Past Presidents ANDREW ELVINS, JOHN A. PATERSON, K.C., M.A.; SIR FREDERICK STUPART, F.R.S.C.; Professor A. T. DELURY, Professor LOUIS B. STEWART, J. S. PLASKETT, B.A., D.Sc., Ottawa; and the presiding officer of each Centre as follows: F. A. MCDIARMID, B.A.; W. A. LOGAN, C.E.; J. M. WILLIAMS; JAMES DUFF, M.A.; C. E. BASTIN, B.A.; Professor W. H. DAY, B.A.; and A. W. MCCURDY.

OTTAWA CENTRE

President—F. A. MCDIARMID, B.A. *Vice-President*—J. J. MCARTHUR.
Secretary—E. A. HODGSON. *Treasurer*—D. B. NUGENT.
Council—DR. W. BELL DAWSON, G. B. DODGE, THOS. FAWCETT.

PETERBOROUGH CENTRE

Local President—W. A. LOGAN, C.E. *Vice-President*—T. A. S. HAY.
Secretary-Treasurer—T. C. ELLIOT.
Council—H. O. FISK, C.E.; DUNCAN WALKER, B.A.; D. E. EASSON, B.A.Sc.; HENRY CARVETH.

HAMILTON CENTRE

Honorary President—WM. BRUCE, J.P.
Local President—J. M. WILLIAMS. *Vice-President*—W. A. ROBINSON.
Secretary—T. H. WINGHAM, B.A. Sc. *Treasurer*—SENECA JONES.
Council—J. J. EVEL, REV. J. J. MORTON, MISS I. M. WALKER.

REGINA CENTRE

Hon. President—DR. W. W. ANDREWS.
Hon. Vice-President—N. MACMURCHY, B.A.
President—JAS. DUFF, M.A. *Vice-President*—MR. TRELEAVEN, B.A.
Secretary-Treasurer—W. G. SCRIMGEOUR, M.A.
Auditor—J. E. CAMPBELL, B.A.
Council—T. H. BISSONNETTE, B.A.; E. R. MURRAY, H. S. MACCLUNG, B.A.; Miss E. D. CATHRO, B.A.

WINNIPEG CENTRE

President—C. E. BASTIN, B.A. *Vice-President*—J. H. KOLB.
Secretary-Treasurer—H. R. KINGSTON, M.A., Ph.D.
Council—REV. FATHER J. BLAIN, S.J.; PROFESSOR NEIL B. MACLEAN, M.A.; PROF. L. A. H. WARREN, M.A., PH.D., F.R.A.S.; F. POWELL, J. W. HARRIS.

GUELPH CENTRE

Honorary President—JAS. DAVISON, B.A.
President—PROFESSOR W. H. DAY, M.A.
1st Vice-President—H. J. B. LEADLAY.
2nd Vice-President—SHERIFF A. S. ALLAN.
Secretary-Treasurer—J. MCNIECE, B.A. *Recorder*—R. R. GRAHAM, B.A.Sc.
Council—MRS. J. J. DREW, MISS MARY MILLS, F. A. GRAESSER, LT.-COLONEL D. MCCREA, H. WESTOBY, COL. JOHN DAVIDSON, J. M. TAYLOR, SR.; COL. A. H. MCDONALD.

VICTORIA CENTRE

Honorary President—DR. J. S. PLASKETT, B.A., D.Sc., Ottawa.
President—A. W. MCCURDY. *Vice-President*—W. S. DREWRY, C.E.
Secretary-Treasurer—DR. L. T. HOUGHTON, M.D. *Auditor*—JAMES FORMAN.
Council—F. NAPIER DENISON, A. SYMONDS, J. E. UMBACH, REV. R. CONNELL, F. C. GREEN, GEORGE S. MCTAVISH, K. M. CHADWICK.

PLATE V.

WILLIAM FREDERICK KING

Late Chief Astronomer for Canada.
Born 1854, died 1916.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. X. JULY-AUGUST, 1916. No. 6

W. F. KING.

BY J. S. PLASKETT

THERE died on Easter Sunday, April 23rd, 1916, Dr. William Frederick King, C.M.G., the Chief Astronomer of Canada, and Director of the Dominion Observatory, the first and foremost patron and organizer of astronomical research in Canada, the founder of the Dominion Observatory, of the Geodetic Survey of Canada and of numerous other scientific activities of the Government.

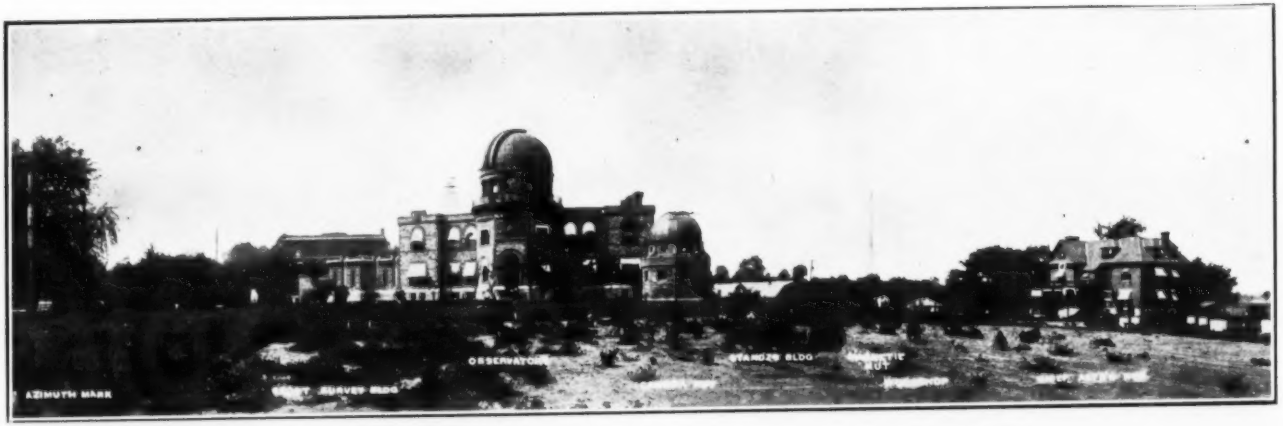
Though of a reticent and unassuming nature, Dr. King's sterling qualities and great ability, combined with a kindly and lovable disposition, had endeared him to a wide circle of friends, and the news of his death came with a great shock and a deep sense of personal loss to all who had been associated with him.

His very reticence, modesty and lack of self-assertion combined to make the knowledge of his work and achievements thoroughly known only to the few who had the privilege of working with him, and I desire in this notice to do some slight measure of justice to the remarkable abilities, the great achievements, and the

beautiful character of this great Canadian. The record of his activities, of his services to science and his country is a long and brilliant one, and every position of responsibility and trust he was called upon to fill, and they were many, was filled in a most satisfactory manner.

He was born at Stowmarket, Suffolk, England, on February 19th, 1854, son of the late William King of the same place and the late Ellen Archer of Mildenhall, Suffolk, who with their family came to Canada in 1862 and settled at Port Hope, Ont. He attended the United Grammar and Common Schools at Port Hope and matriculated in Arts at the University of Toronto in 1869. At the close of his third year at the University he was appointed to a position on the staff of H.B.M. North American Boundary Commission—Lake of the Woods to Rocky Mountains—thus beginning at the age of eighteen what was to be an important part of his life's work. He returned to the University in December, 1874, and graduated with the degree of B.A. in 1875 with high honors, obtaining the gold medal in mathematics. His standing in the class lists has never been surpassed, and his course throughout, as indicated by his obtaining seven scholarships, was an exceptionally brilliant one. Dr. King was a masterly mathematician and to the end of his life spent much of his leisure in intricate mathematical calculations, being particularly interested in the theory of numbers. It was, however, a means to a practical end with him, and not the end itself, and much of his success has undoubtedly been due to his remarkable grasp of mathematical questions and facility in mathematical analysis and to the closely allied faculty of logical and accurate analysis in problems of all kinds.

In 1876 he was admitted to the standing of D.L.S. (Dominion Land Surveyor) and D.T.S. (Dominion Topographical Surveyor), being the first to receive the latter commission. In June, 1904, the honorary degree of LL.D. was conferred on him by his Alma Mater. He was elected Honorary President of the Royal Astronomical Society of Canada in 1906, which position he held until his death, and was made a Fellow in 1909. He was elected to Fel-



DOMINION ASTRONOMICAL OBSERVATORY

With the various buildings connected with it, Ottawa, Canada.

lowship in the Royal Society of Canada in 1908 and to its Presidency (the highest scientific honor in Canada) in 1911. He was a member of the American Astronomical Society, a Fellow of the American Association for the Advancement of Science, and a member of several other learned and scientific societies.

He entered the service of the Dominion Government on September 1st, 1872, and, except for the six months in 1875, when he obtained his degree, his services have since been continuously devoted to his country and are one long and brilliant record of achievements, appointments and honors. In 1875 and 1876 he was Astronomical Assistant on the Special Survey in the North West Territories, and from 1877 to 1881 was in charge of the Astronomical section of this survey. His first permanent appointment as Inspector of Surveys, Interior Department, was of date June 13th, 1881, and was followed by his appointment as Chief Inspector in 1886. He was appointed Chief Astronomer in 1890, Director of the Dominion Observatory in 1905, and Superintendent of the Geodetic Survey of Canada in 1909. When Dr. King's modest and retiring disposition is considered, these important appointments form striking evidence of his great mathematical and scientific ability.

In addition to his permanent work in these departments, of which the Observatory and the Geodetic Survey are standing memorials, Dr. King has performed very valuable service in the various boundary questions which have arisen between Canada and the United States. The keenness and judicial bent of his mind enabled him to grasp quickly and present clearly the essential features of any question, and this was soon and continuously realized by the Government. His numerous appointments as H.M. Commissioner for various sections of the International Boundary in 1892, 1899, 1901, 1902, 1904, 1906, 1908, are evidences of the value placed on his services in such important matters. He was appointed on the International Waterways Commission, serving from 1903 to 1907, and was representative of the Canadian Government in the uses of international waters for irrigation in

1908. It was probably largely owing to his invaluable services on international boundaries and these allied questions, that he was created Companion of the Order of St. Michael and St. George on June 26th, 1908.

Dr. King's greatest work on behalf of pure science, and the one of greatest moment and interest to astronomers, was the founding and organization of the Dominion Observatory. He began to urge the construction of an observatory for Canada, at first on a very modest scale, over twenty-five years ago, and, though not for some time successful, he persevered in his quiet yet effective way and gradually brought the Government to see the value and need of such an institution. It was not, however, until the administration of the Hon. Clifford Sifton in the Interior Department that the matter took concrete shape, and success finally crowned his efforts. Mr. Sifton recognized fully the high attainments of Dr. King, and his great services to the country in boundary questions, and especially in his preparation of the Canadian case for the Alaska Boundary Tribunal, and saw clearly the advantages of a national observatory.

Construction of the observatory building, a handsome stone structure on the Experimental Farm, was commenced in 1903, the telescope, a 15-inch refractor, optical parts by Brashear, mounting by Warner & Swasey, was installed in the fall of 1904, and the staff occupied the building in the spring of 1905. The work of the Observatory, as organized and fostered by Dr. King, embraced a wide range of scientific investigation in astronomy and geophysics. In astronomy the work embraces:—stellar radial velocity determinations, principally of spectroscopic binaries, micrometric measures of double stars, comet and stellar photography, photographic photometry, meridian observations for star positions and for time, maintenance of an accurate time service in Government buildings, determination of longitude and latitude, the former by means of ordinary and wireless telegraphy, at various places distributed over the country; and solar research along various lines,

lowship in the Royal Society of Canada in 1908 and to its Presidency (the highest scientific honor in Canada) in 1911. He was a member of the American Astronomical Society, a Fellow of the American Association for the Advancement of Science, and a member of several other learned and scientific societies.

He entered the service of the Dominion Government on September 1st, 1872, and, except for the six months in 1875, when he obtained his degree, his services have since been continuously devoted to his country and are one long and brilliant record of achievements, appointments and honors. In 1875 and 1876 he was Astronomical Assistant on the Special Survey in the North West Territories, and from 1877 to 1881 was in charge of the Astronomical section of this survey. His first permanent appointment as Inspector of Surveys, Interior Department, was of date June 13th, 1881, and was followed by his appointment as Chief Inspector in 1886. He was appointed Chief Astronomer in 1890, Director of the Dominion Observatory in 1905, and Superintendent of the Geodetic Survey of Canada in 1909. When Dr. King's modest and retiring disposition is considered, these important appointments form striking evidence of his great mathematical and scientific ability.

In addition to his permanent work in these departments, of which the Observatory and the Geodetic Survey are standing memorials, Dr. King has performed very valuable service in the various boundary questions which have arisen between Canada and the United States. The keenness and judicial bent of his mind enabled him to grasp quickly and present clearly the essential features of any question, and this was soon and continuously realized by the Government. His numerous appointments as H.M. Commissioner for various sections of the International Boundary in 1892, 1899, 1901, 1902, 1904, 1906, 1908, are evidences of the value placed on his services in such important matters. He was appointed on the International Waterways Commission, serving from 1903 to 1907, and was representative of the Canadian Government in the uses of international waters for irrigation in

1908. It was probably largely owing to his invaluable services on international boundaries and these allied questions, that he was created Companion of the Order of St. Michael and St. George on June 26th, 1908.

Dr. King's greatest work on behalf of pure science, and the one of greatest moment and interest to astronomers, was the founding and organization of the Dominion Observatory. He began to urge the construction of an observatory for Canada, at first on a very modest scale, over twenty-five years ago, and, though not for some time successful, he persevered in his quiet yet effective way and gradually brought the Government to see the value and need of such an institution. It was not, however, until the administration of the Hon. Clifford Sifton in the Interior Department that the matter took concrete shape, and success finally crowned his efforts. Mr. Sifton recognized fully the high attainments of Dr. King, and his great services to the country in boundary questions, and especially in his preparation of the Canadian case for the Alaska Boundary Tribunal, and saw clearly the advantages of a national observatory.

Construction of the observatory building, a handsome stone structure on the Experimental Farm, was commenced in 1903, the telescope, a 15-inch refractor, optical parts by Brashear, mounting by Warner & Swasey, was installed in the fall of 1904, and the staff occupied the building in the spring of 1905. The work of the Observatory, as organized and fostered by Dr. King, embraced a wide range of scientific investigation in astronomy and geophysics. In astronomy the work embraces:—stellar radial velocity determinations, principally of spectroscopic binaries, micrometric measures of double stars, comet and stellar photography, photographic photometry, meridian observations for star positions and for time, maintenance of an accurate time service in Government buildings, determination of longitude and latitude, the former by means of ordinary and wireless telegraphy, at various places distributed over the country; and solar research along various lines,

principally spectroscopic determination of the solar rotation. In Geophysics an almost equally wide range is covered. Seismological investigations with the most recent type of horizontal and vertical recording instruments are continuously carried on; and the terrestrial magnetic elements and the value of gravity at various stations throughout the country are accurately observed.

Although Dr. King's administrative duties prevented him from taking an active part in any of these researches, he had a wide general and detailed knowledge of each and his suggestions, especially along the mathematical and dynamical sides of the various problems arising, were always helpful and frequently introduced entirely new conceptions and methods. He had the extremely rare and happy faculty of inspiring enthusiasm in the members of his staff, and his evident trust in them and his determined policy of non-interference in details and generous supply of all needful apparatus served to urge them to greater efforts. That this policy was successful is clearly shown by the quality and quantity of astronomical and geophysical work produced by the observatory staff. Although only organized about ten years, the Dominion Observatory already holds a deservedly high rank in the scientific world.

Canada's modest equipment for astronomical research will shortly be greatly increased by the completion of the 72-inch reflecting telescope, larger than any now in existence. This project was first brought formally to the attention of the Government by a memorial from the Royal Society of Canada, supplemented by resolutions of the American Astronomical Society and the Royal Astronomical Society of Canada. It is undoubted, however, that the confidence and high esteem with which Dr. King was regarded by the Government were large factors in obtaining its consent to proceed with the work. It is very greatly to be regretted that Dr. King did not live to see this final fruit of his years of faithful service brought into active use.

But the Boundary Surveys and the Observatory by no means

complete the record of his scientific activities in the Government. For a number of years efforts had been made by various scientific and engineering societies to have a Geodetic Survey of Canada initiated. Dr. King's persistent and able efforts, coupled with diplomatic and well-timed action, enabled him to succeed where others had failed, and primary triangulation was started in a modest way. This action was formally ratified and the survey properly organized in 1909, with his appointment as Superintendent of the Geodetic Survey. This important work has been energetically prosecuted, and we may soon hope to possess a system of primary points accurately determined, both in position and elevation, over the principal settled portions of the country.

It might have been thought that the administrative and technical work entailed in the management of three such diversified departments as the Boundary Survey, the Observatory, and the Geodetic Survey, would have occupied his whole attention, but he nevertheless found time to prepare several scientific papers for publication. The most important of these, "The Geometry of Orbits," is a classic on the subject and presented an entirely original and ingenious method of obtaining graphically the elements of the orbit of a spectroscopic binary. This method is used here and elsewhere in binary work. Most of the useful tables published in the Manual of Instructions for the Survey of Dominion Lands were computed by Dr. King, and his Departmental Reports contained much matter of great scientific and practical value.

Dr. King took a very active part in the work of the Royal Astronomical Society of Canada, being foremost in the formation of the centre at Ottawa and in the enlargement of the sphere of the parent Society at Toronto. He was the first President at Ottawa and has been Honorary President of the whole Society since 1906. He has always taken great interest in and presented many valuable papers to the meetings at Ottawa, several of which have been published in this JOURNAL.

Through all these manifold activities and honors, Dr. King

maintained the same quiet, unassuming, even reticent manner. Any idea of talking of himself or even hinting at his own capacity or achievements was entirely foreign to his nature, and in consequence very few people outside of his staff and those he was associated with in the Department even faintly realized his great attainments and his splendid scientific and public services, or had any adequate conception of the great and many-sided scientific department he had built up.

The great respect, admiration and affection with which his staff regarded him was manifested on June 13th, 1911, the thirtieth anniversary of his entrance into the permanent service of the Dominion Government, by the presentation to him of a magnificent silver loving cup. A record of his achievements, appointments and academic and other distinctions is engraved on this cup, and there is a feeling of deep satisfaction among his staff that at least this one tangible mark of their esteem was made before his death. In Dr. King the staffs of the Observatory and of the Boundary and Geodetic Surveys have lost a Chief in whom the most considerate, kindly and generous treatment of his officers was combined with a full measure of trust and confidence in them, a settled policy of Dr. King's that spurred the great majority to redoubled efforts in their work. I am sure I voice the sentiments of his entire force in expressing my sense of deep personal grief and loss at his too early death and my conviction that no one can be found to take the place he occupied in the administration of the Observatory and Surveys, in the confidence of the Government or in the affection and admiration of his staff.

Dr. King took a very active part in Church matters, was a prominent member of St. George's Church (Anglican), Ottawa, filling in succession all the important lay offices in the Parish, and was at the time of his death lay representative to the Provincial and General Synods.

He was married in 1881 to Augusta Florence Snow, daughter of John A. Snow, D.L.S., and leaves to mourn his loss his widow, two sons, Frederick W. and Edward A., at home, and one daugh-

ter, Mrs. R. M. Motherwell. Of his father's family, one sister only, Mrs. James Reid, of Port Hope, survives him.

In the death of Dr. W. F. King, besides a devoted and valuable officer, Canada has lost a man of surpassing intellect, high scientific attainments and the strictest integrity, and a pioneer in the establishment and advancement of scientific research. He was truly one of Canada's great men, and the loss to the country he so ably served and represented is irreparable.

DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA.

TELESCOPE PIER AND FOUNDATION FOR BUILDING

Saanich Hill, Victoria, B.C.

THE 72-INCH REFLECTING TELESCOPE.

By J. S. Plaskett

THE completion of the mechanical parts or mounting of the 72-inch telescope and the near approach to completion and erection of building and dome for the telescope make it fitting to present to readers of the Journal a short note, illustrated by some photographs, of the present condition of the enterprise.

The mounting of the telescope was practically completed, and it was temporarily erected in the factory of the makers, the Warner and Swasey Co., of Cleveland, Ohio, about the end of March last. Some finishing touches to one or two details, the holding of a formal reception and exhibition of the telescope, which was delayed by the absence of members of the firm until May 25th, and the fact that the dome was not sufficiently advanced to offer protection from the weather, caused the postponement of the shipment to Victoria until the early part of June. The erection of the mounting will occupy some three months, hence occurring during the most favorable season, and should be completed by the early autumn.

The 73-inch mirror is 12 inches thick at the edge, has a hole 10⅛ inches in diameter through the centre, and weighs some 4,340 pounds. It is finished on edges and back and its front surface is now practically spherical. Before it can be made a paraboloid of revolution, which is the surface necessary to bring the parallel pencil of light from any celestial object accurately to a focus, it is necessary to prepare a large flat surface for the purpose of testing the paraboloid. It is hoped that this will be finished and the mirror completed as soon as the mounting is ready to receive it.

A fine road to the summit of Saanich Hill, the site of the new observatory, was completed early last spring by the Govern-

ment of British Columbia, which has most promptly fulfilled its undertakings in the matter. Although the first source of water supply was a failure, this important question is now satisfactorily solved.

The concrete pier for carrying the telescope (Plate VII.), and the surrounding circular steel building (Plate VIII.), whose wall serves to support the dome, was commenced last summer and is now completed, except for some minor details, which are delayed until the telescope arrives. One of the essential features about the building and dome is that they are entirely of steel construction, which allows them to assume rapidly the air temperature; and they are provided with double walls and a system of louvres at the top of the dome, ensuring a thorough circulation of the air and the maintenance of the interior at the shade temperature.

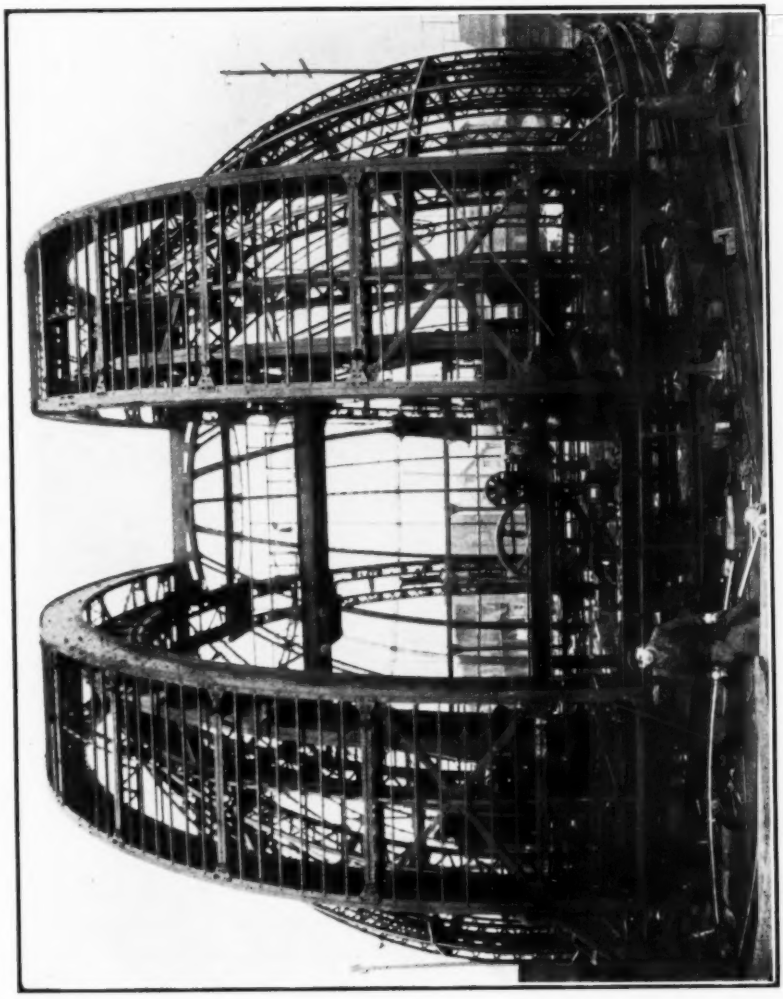
A contract for the 66-foot revolving dome, which, in the case of a large reflecting telescope, is a most important part of the equipment, as it has to be provided with many accessories required in the handling of and observing with the telescope, was awarded last spring to the Warner and Swasey Co., so that dome and telescope were designed together and should work in proper relation to one another. This dome is now being erected on its building at the observatory site, and although it has not yet been operated, its temporary erection at Cleveland sufficed to show that it will be the most complete and convenient in every operating detail of any ever built. (Plate IX.)

One of the observers' houses is completed, but none of the other buildings required have yet been begun. This dwelling will enable the supervision of the erection of dome and telescope, and the preliminary adjustments and experimental work to be efficiently performed. It is hoped that by the time the telescope is in shape for regular and systematic operation the necessary additional building equipment will be provided.

It may be of interest to give a summary of the main features of the telescope mounting at this time, leaving a full account until its final erection and completion.

PLATE VIII.

STRUCTURAL STEEL FRAMEWORK OF TELESCOPE BUILDING SURROUNDING TELESCOPE PIER



DOME FOR THE 72-INCH REFLECTOR,
As temporarily mounted at Cleveland, Ohio.

The telescope is to be used in three different forms, observations being made at the prime focus, at the Newtonian focus or at the Cassegrain focus. In the photography of the heavenly bodies, or in obtaining spectra of very faint objects, the photographic plate or small spectrograph may be placed at the upper end of the tube in the prime focus, 30 feet above the great mirror. In the Newtonian form a plane mirror 19 inches in diameter, about 4 feet down the tube and inclined at 45°, reflects the light to a focus on the plate or spectrograph at the side of the tube. In the Cassegrain form a convex mirror 19 inches in diameter, placed 7 feet below the prime focus, reflects the light back through the central hole of the main mirror to a focus below the mirror cell, where it can be visually observed, photographed or analysed by the spectrograph. The equivalent focal length of this combination is 108 feet, giving images of exactly the same size as a refractor with a tube 108 feet long.

The function of the mechanical parts or mounting of this or any telescope is to hold the optical parts invariably, and at the same time without flexure or strain, in their correct relative positions, to enable them to be readily pointed to any desired object, and to move them as a whole delicately and accurately to follow the motion of the stars. Evidently in the case of a great telescope like the 72-inch, whose moving parts weigh some 45 tons, this is an engineering problem of a very exacting character. The previous experience of the makers in the design and construction of the largest refracting telescopes in the world, the Yerkes 40-inch, the Lick 36-inch, and many others, has been of great value in this connection. Further, the great advances in recent years in the production of high grade steel castings, in the manufacture of bearings in which friction has been reduced to a minimum, and in other directions has enabled a telescope to be constructed which is not only considerably larger in size but is superior in design, in accuracy, and in convenience and smoothness of operation to any existing instrument.

The telescope, whose general form follows the English type

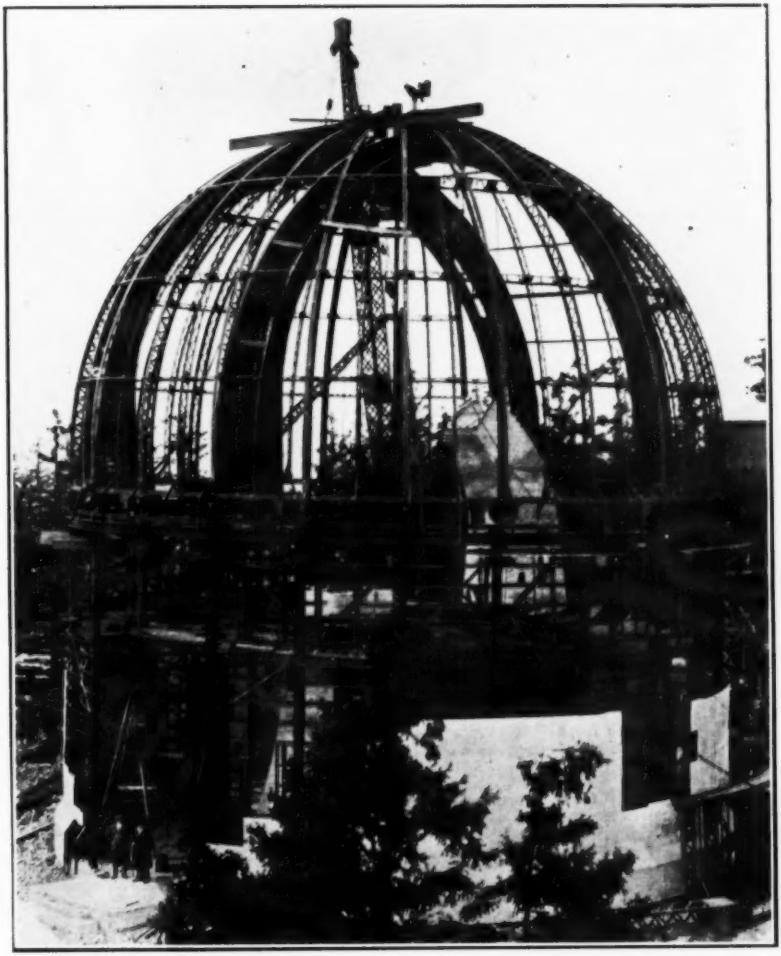
of equatorial mounting and is well shown in the photograph (Plate XI.), has a long polar axis supported at its north and south ends by bearings, in a direction parallel to the earth's axis. The declination axis, to which the tube is attached at right angles, passes rectangularly through the central cubical portion of the polar axis, the weight of the tube on one side being counterpoised by the declination gearing and housing on the other.

The polar axis is composed of three sections, all of the best steel castings, firmly bolted together, namely, the central cubical section above mentioned and north and south conical tubular sections. It is nearly 23 feet long and weighs about ten tons. The declination axis is a steel forging, 5¼ tons in weight, 14½ feet long, 15½ inches in diameter, with a flange 41 inches in diameter and 4 inches thick, to which the tube is bolted. The tube is also in three sections, the central cylindrical steel casting, about 7½ feet in diameter and 6 feet long, weighing 7 tons, being attached to the flange of declination axis; to its bottom flange is bolted the steel mirror cell, weighing, with mirror counterpoises and mirror, 6 tons; while to its upper end is firmly attached the skeleton tube, a beautifully designed and extremely rigid piece of structural work, upwards of 23 feet long, 7½ feet in diameter, and weighing, with attachments, about 2 tons.

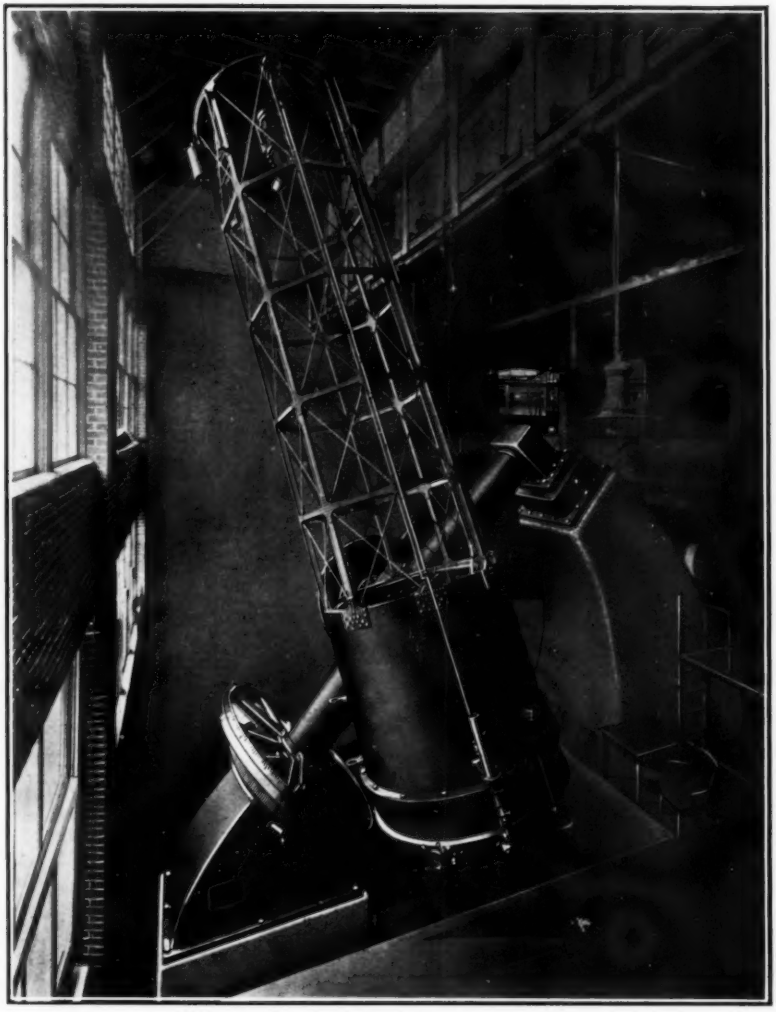
Below the mirror cell the spectrograph and visual appliances for use at the Cassegrain focus are attached. At the upper end of the skeleton tube an exceedingly ingenious arrangement, avoiding the use of several heavy and awkward extensions of the skeleton tube which were necessary with all previous reflectors, enables either the prime focus, Newtonian or Cassegrain attachments to be used at will and with the minimum of trouble and delay in changing from one to the other.

The driving clock, similar in design to that which has been so successful in the Lick and Yerkes telescopes, moves the telescope in right ascension by means of an accurately cut worm-wheel, 9 feet in diameter, mounted on the polar axis by ball and ball thrust bearings, and clamped to it when required by an electric motor.

PLATE X.



DOME AND BUILDING,
May 5, 1916.



THE MOUNTING OF THE 72-INCH REFLECTING TELESCOPE

Temporarily erected at Cleveland, Ohio

The telescope is moved from one position to another and set and guided wholly by electric power, no less than seven motors besides several solenoids and magnetic clutches being required for these motions. The quick motion motors move the telescope at the rate of 45° per minute, one revolution in 8 minutes, in both coordinates. The slow motions have two speeds, a fast one for fine setting at the rate of one revolution in 36 hours, and a slow one for guiding, one revolution in 720 hours or 30 days. With the Cassegrain focal length of 108 feet the guiding speed of the star image at the focal plane is 1/300 inch per second or 1/5 inch per minute.

The electric wiring and control systems have been very carefully worked out, all sliding brush contacts avoided, and the whole system installed in a permanent and yet easily accessible form, giving the maximum of convenience in operation with the minimum of attention and repair. The method of operation will be as follows:—An operator on the observing floor controls the quick motions and clamps of the telescope and the rotation of the dome from the more convenient of two switchboards, one on the east and the other on the west side of the south pier, the telescope being quickly set approximately to the tabular position of the desired object by the sidereal and declination setting circles. The observer at either the upper or lower ends of the tube can clamp or unclamp the telescope, make the fine settings and guide by means of push buttons located on a small keyboard which he can carry around with him or attach to any convenient place.

Every attachment that will add to the convenience and accuracy of operation of the telescope has been provided and the instrument can be handled with great ease and moves with great smoothness. A very slight pressure at the upper end of the tube suffices to set it in motion in either right ascension or declination, and some idea of the ease with which it moves is conveyed by the fact the actual increase of current required to move the telescope in quick motion over that needed to run the motors idle is barely sufficient to light a 16 c.-p. lamp. These small forces show, when

the great mass, 45 tons, of the moving parts is considered; the perfection of design and workmanship in the instrument.

I desire to place on record my appreciation of the spirit which has governed the Warner and Swasey Co. throughout the design and construction of this telescope. Their ideal has been to make this instrument the most accurate, perfect running, and convenient of any ever constructed, and to that end no pains or expense has been spared. When to this purpose is added their unequalled experience in the design and construction of large telescopes, and their unrivalled facilities for producing the highest grade of workmanship, the result can not fail to be, and undoubtedly is, an instrument of the greatest accuracy and one in which every needful and desirable attachment or movement is provided in the most direct and simple way.

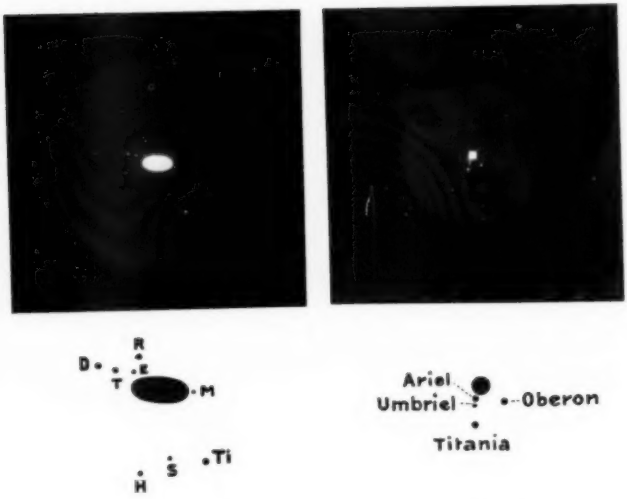
The cause of astronomical research in Canada is to be congratulated that this great addition to its equipment was entrusted to such capable and sympathetic hands, and that this magnificent instrument has been so promptly and adequately completed.

PLATE XII.

SOUTH

SATURN
1916, Feb. 25d 10h 46m
Exposure 25 secs.

URANUS
1915, Sept. 6d 10h 7m M.M.T.
Exposure 5 min.



DIRECT PHOTOGRAPHS OF SATURN AND URANUS AND THEIR SATELLITES

By C. O. Lampland, of the Lowell Observatory.

Enlarged 3¼ times original.

These were taken at the principal focus of the 40-inch reflector, and as they were timed to bring out the satellites, the image of the planet at the centre is much over-exposed.

A key to the satellites is shown below each photograph. For Saturn, **M** is Mimas, **E** Enceladus, **T** Tethys, **D** Dione, **R** Rhea, **Ti** Titan. Iapetus was beyond the field here shown.

All the satellites marked in the keys are clearly shown on the originals but some of the faint ones are lost in the reproduction. Other bright images seen on the plates are due to stars in the field of the planet at the time.

THE GENESIS OF PLANETS*

By Percival Lowell

THE birth of our present solar system was probably catastrophic. Two suns met and we were the outcome. Meteorites are our informants of the fact. For the meteorites we encounter on starlit nights show by their occluded gases that they once formed part of a large heated body, which was then shattered by a collision or near collision with another of its kind; and, as I pointed out long ago, that they move in ellipses about our sun points to our sun as that dismembered body and to themselves as the yet ungathered remnants of the shock.

As to what subsequently occurred, we have no analogy to guide us, for the spiral nebulæ indicate themselves to be galaxies, not solar systems in course of construction. Pure reasoning must inform us, if it can, of our far-time history.

Such a catastrophe as I have outlined would apparently result in a lens-shaped disc, most of the matter lying approximately in the plane of the moving bodies, the scanty amount thrown off outside it going to make the comets. The matter would not be evenly distributed throughout the plane; but have denser and sparser portions, the denser forming nuclei for subsequent aggregation.

Conceive then, particles — meteorites — revolving in ellipses around the central mass. Their orbits would be ellipses because under the permanent control of that mass. The mean distance would be the same as the major axis, since $r = a +$ periodic terms. For simplicity, then, we may consider the orbits circles — now the speed in a circle under gravity is $v^2 = m/r$, m being the mass of the central body and r the distance of the nucleus from the sun. Suppose, within the space throughout which

* Address before the Royal Astronomical Society of Canada, April 27, 1916.

particles are to be gathered up, the distribution of the meteorites to be uniform, and consider two particles at distance ρ within and without the nucleus. Such particles would have speeds

$$v_1 = \frac{1}{(r - \rho)^{1/2}} \text{ and } v_2 = \frac{1}{(r + \rho)^{1/2}}$$

Expanding these expressions, we get

$$v_2 = \frac{1}{r^{1/2}} - \frac{\rho}{2\,r^{3/2}} + \frac{3}{8}\frac{\rho^2}{r^{5/2}} - \frac{5}{16}\frac{\rho^3}{r^{7/2}}$$

$$\text{and } v_1 = \frac{1}{r^{1/2}} + \frac{\rho}{2\,r^{3/2}} + \frac{3}{8}\frac{\rho^2}{r^{5/2}} + \frac{5}{16}\frac{\rho^3}{r^{7/2}}$$

The first particle would overtake the nucleus, the second be overtaken by it. The two would form a couple turning the nucleus in a retrograde direction, that is opposite in sense to the revolution of the nucleus round the sun.

Now we notice that there would be no rotation round an axis in the plane of the nucleus' orbit, because particles arriving above and below this place would neutralize one another's action in pairs. Secondly, neglecting quantities of the third order in ρ, the speed at any point ρ would be as ρ. Hence the spin would be uniform.

We also notice that this would be a stable arrangement were it not for original differences of density and motion due to the attraction of the nucleus; for the centrifugal force $\omega^2 r$, in which ω is the angular velocity, would be exactly counter-balanced by the attraction at any point in a homogeneous mass since that attraction also is as r.

Of course original differences of density would exist and the attraction of the nucleus would make itself felt. But approximately we may say that, formed in this way, a planet would be born with a uniform retrograde spin as a birthright.

This marks the first stage in a planet's history.

The second stage in a planet's evolution is the condensing of the matter it has brought together. Unless the aggregation were rotating as fast as it could without disruption at the start, condensation must occur. The heavy particles would fall fastest

to the centre, because of the less relative resistance they would suffer. Just as a bullet falls in the air faster than a feather, not because gravity is greater, but resistance less.

As the particles neared the centre, they would whirl faster because of the conservation of rotary momentum. For, perhaps, the most fundamental of physical laws, the most truly elemental one, is the unchangeableness of the moment of momentum. Every boy without realizing it is perfectly familiar with the fact, in whirling a stone attached to a string round his finger and watching the stone go faster as it winds up.

The law expressed analytically is

$$v\,r = \omega\,r^2 = \text{a constant.}$$

Whence if r be diminished v must increase.

Now increase in v and decrease in r both increase the centrifugal force, for the force is v^2/r.

Furthermore, increase in the centrifugal force increases the oblateness of the mass. Consequently, as the planet becomes non-homogeneous the internal layers rotate faster and their spheroidal shape is accentuated.

Heat is generated in this process by the tumbling in. And the body from an original cool state (roughly speaking) of the coldness of space, becomes hotter and hotter, depending for absolute temperature upon its mass. So great are the planetary masses that this results in making them molten.

The process of condensation is naturally delayed by the heat evolved, which tends to expand the body. But when heated enough to become gaseous throughout it actually grows hotter as it contracts, as Lane showed forty odd years ago.

The third stage sets in when the body has so far cooled as to become liquid or solid throughout, so far at least as the matter composing it is capable of condensation at its then temperature and pressure. For a covering of air would remain for some time, a subject we shall not here touch upon. Up to now the planet's

spin has been increasing. From this point on its rotational speed diminishes owing to the tidal pull upon its mass by the sun. A tidal pull has acted upon it from its birth, but has hitherto been more than counteracted by the increased spin due to its shrinkage.

The end is planetary death, when tidal friction has done its work and caused the body to turn the same side in perpetuity to the Sun. Mercury and Venus have reached this, the fourth stage in planetary evolution and are now white planet corpses, circling unchanging, except for libration, around the Sun.

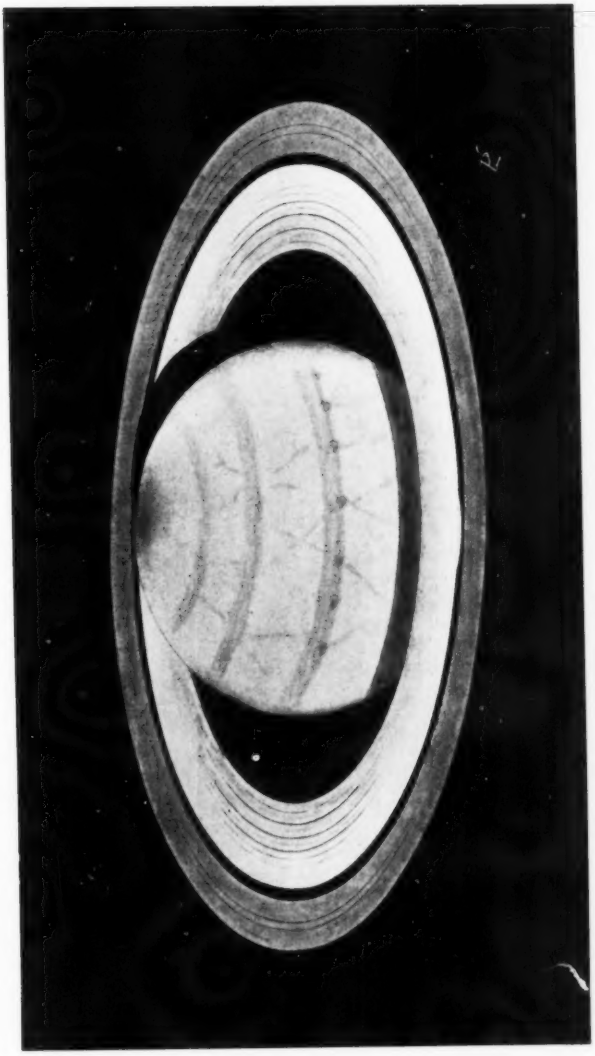
Thus the three stages of a planet's life-history are characterized by different degrees of rotational speed, oblateness and matter-distribution. In the course of the three the spin starts at a certain amount, rises to a maximum and sinks to a minimum at the end. The body's contour does the same, beginning as an oblate spheroid, increasing at first in oblateness and afterwards diminishing to practical rotundity. Thirdly, the body originates homogeneous, becomes heterogeneous and thence grows more homogeneous again to a certain limit, beyond which it cannot pass.

Uranus.—Of these three stages in planetary evolution, we have approximate examples in Uranus, Saturn and Mars; Uranus representing the first, Saturn the second, and Mars the third. It is significant, too, that such, inversely, is their order in distance from the Sun, though their size is a potent factor in the result.

Uranus is so far away from us that he was not even known until a century and a quarter ago. There is a tradition that the Polynesians had previously detected him and knew him for a wandering star. It is possible, but not likely; for though he can be seen with the naked eye when one knows where to look for him, to have picked him out by his motions would be like discovering the proverbial pin in the proverbial haystack.

Nor did the telescope do much more than record his positions for a hundred years after he was known. It was not till toward the end of the nineteenth century that we really made his personal acquaintance. Since then, beginning practically with

PLATE XIII.



SATURN — OPPOSITION 1914–15
Drawn by Percival Lowell

Schiaparelli and Young, we have been learning about him, though his little sea-green disk is anything but self-committal. Indeed, till just recently we did not know his spin, in popular language his day. This was a serious lack to understanding him, as we shall see.

To discover his day had for some time been a prime desideratum of planetary astronomy; not that his day made any difference to him, for he is in his blind-puppy stage when days do not count. But it was vital to any knowledge of the way in which his body was constituted, to say nothing of the relation his satellites bore to his spin. For perhaps one of the most impressive powers of mathematical astronomy is its ability to discern what lies forever hid to the eye, the internal constitution of a planet.

Now celestial mechanics connect together, supposing a body to turn of a piece, its mass, spin, oblateness and internal density-distribution. So that if the first three of these quantities be known, the last can be found. The limits between which the latter can lie are homogeneity on the one hand and central concentration on the other; for the matter could not possibly be denser outward than inward. Without going into the mathematics of the case, it is evident that, if the body spin of a piece, homogeneity will make it flatter than would central condensation, because at the surface the centrifugal force is greatest and there is less matter internally to pull it in. An oblateness between the two will therefore correspond to an internal distribution between the two limits.

For all the planets inside of Uranus, it has long been possible to calculate this distribution, supposing a uniform spin. But for Uranus it has not been possible, because we did not know his rotation time. In 1910 the subject was taken up at Flagstaff spectrographically; the only way in which any trustworthy result could possibly be got, because of the feebleness of the planet's belts. For not only must the belts be seen, but some salient marking on those belts must be well enough described to permit of visual timing. Even spectrographically the problem was a very difficult one and had hitherto defied detection. In Dr. V. M. Slipher's hands, how-

ever, the thing was accomplished, and spectrograms obtained which permitted of measurement.

The way in which the spectroscope detects planetary rotation is as follows. The slit is placed parallel to the planet's equator. Then if the body be rotating, one end of the image made by the slit will be coming toward the observer, while the other one is going away from him. Now motion in the line of sight shifts the spectral lines toward the red, for recession; toward the violet, for approach. The result is to pivot the lines along their centres, inclining them in the spectrographic pictures. Measurement of the amount of the tilt will then give the ratio of the recession and advance in terms of the velocity of light and so of miles a minute. Whence, we deduce the period of its spin. In the case of Uranus the tilt of the spectral lines, though very minute, proved measurable, and gave 10¾ hours for the Uranian day.

Here, then, we were supplied with the last link in the mathematical chain of reasoning leading to a knowledge of the distribution of the matter composing him, on the supposition that he rotates all together. Then came a surprise. For when the equations were solved, a strange anomally stood disclosed. From his superficial look we should have placed Uranus in the same category as Jupiter and Saturn. For he appears like a miniature Saturn minus a ring. But the discovery of his day put a totally new light on the subject. It showed that, inside of what we see, his constitution must be quite different from those major planets. Jupiter and Saturn, on the supposition of uniform spin, are 31 per cent. and 24 per cent. of the way from central concentration to homogeneity, Uranus came out 87 per cent., as far removed from central concentration as Mars; more nearly homogeneous even than the Earth. Yet his mean density was totally unlike theirs, being strictly akin to that of the giant planets, nearer that of water than rock. This, as we saw in theory, marks him off as belonging to a very different phase of evolution from ourselves or our immediate neighbors, exhibiting a phase at the other extreme of planetary history, the incipient state of a planet's career as against the far

advanced. In Uranus, then, we behold a planet not long removed from its beginning, a body in its babyhood in fact.

In addition to what the spectroscope has taught us, the telescope has done its share on Uranus at Flagstaff, and photography as well. We thus have determinations of the diameter, oblateness, volume, rotation-sense and period as also photographic positions and magnitudes of his satellites made under the most favorable conditions so far obtained. The results for his bodily elements are summarized in the following table.

Equatorial diameter at distance unity, a	= 72″·33	= 8·22 times the earth's
Polar " " " " b	= 66″·03	
Oblateness	$= \frac{1}{11{\cdot}5}$	
Volume	= 63·3	
Mass	= 14·65 (Hall) 14·80 (Gaillot)	"
Mean Density	= ·231 ·234	"
Rotation Period	= $10\frac{1}{4}$ hours	
Mean density compared with water	= 1·28	

Polar axis perpendicular to the plane of the orbits of the satellites; judged from the position of the belts. In these measures irradiation has been taken into account.

Saturn.—The second stage in the history of a planet is exemplified by Saturn.

Very recently we have learnt something about him interesting and important in itself, and doubly so from the way it was acquired. For Saturn was not the one to impart it; the rings proved the telltale in the case. The discovery was due: first to the detection of certain hitherto unknown features of the ring-system, and secondly to what celestial mechanics in explanation showed them to lead. Although the facts never could have been learnt without the application of advanced mathematics, for they depended upon the exact correlation of quantitative amounts, the method may be made intelligible to intelligent laymen, or non-mathematical astronomers.

If we have two bodies travelling round a third, each of these bodies will disturb the otherwise simple elliptic movement of the

other. If in addition their periods be commensurate, the disturbances occasioned will occur over and over again in the same parts of the orbits, and in consequence be cumulative, until finally the periods are so changed as to become incommensurate, after which the bodies will meet consecutively at different points and a compensation in disturbance be brought about. Commensurability of period is thus an unstable state of planetary equilibrium, incommensurability a stable one.

It used to be thought that this was not a necessary deduction and that the bodies might simply swing through their commensurate periods with a certain libratory action, remaining out much longer than in. But this is now known to be generally not the case. Studies by the writer have shown that there is no instance of libration among the asteroids and that the larger planets are all placed where permanent incommensurability of period exists. Indeed, after ascertaining the fact and pursuing the investigation, he found a term in the second order of the masses in the perturbing function which assured this state of things.

Now the informant features discovered in the ring-system were the presence of certain permanent divisions in it, in addition to the large ones, such as Cassini's, previously known. These new divisions, as well as the old ones, were not only seen but measured. When their distances from Saturn's centre were compared with Mimas', Saturn's nearest satellite, the ratios of the corresponding periods proved commensurable, as Kirkwood had found long ago at Cassini's. They paralleled the gaps in the series of major axes of the asteroids. Thus they showed themselves to be due to the perturbative action of Mimas, just as those of the asteroids are due to Jupiter. But though the parallelism was conclusive, both the new and the old divisions all displayed minute discrepancies from the positions assigned them by theory, and furthermore they showed themselves governed in this by a certain law, for the discrepancies increased systematically with increased proximity to the planet.

To what could this disregard of theory, yet law-abiding di-

vergence, be due? That it was not due to any error in measurement nor to error in the data of the Saturnian system was proved by recalculation, assuming such errors to exist within any possible limits. It was not in the micrometer constant, not in Saturn's oblateness, not in Saturn's mass. Yet clearly Saturn's attraction on bodies near him needed to be increased to explain the divisions, for they were all too far out for their periods, a thing only to be accounted for by supposing a greater inward pull. But on the received idea that the planet rotated uniformly throughout, this could not be done.

To explain the discrepancies the old idea must be abandoned and some other found to take its place. It must be something, too, which not only increased his pull but increased it progressively as one neared his surface. Greater oblateness could do this, for the resulting oblateness would cause a greater attraction because a spheroid in proportion to its flattening attracts more than a sphere in the plane of its equator and increasingly so as one nears its surface from without. But superficial oblateness is barred, because we know what that is, and no allowable change is sufficient. Oblateness must be sought within. Now if the planet be supposed to consist of different layers, rotating faster inside than out, the inner ones would be more oblate than on the supposition of uniform spin. Here, then, is a clue. To follow it up is our next step.

The problem is to find an oblateness conformable internally to the laws of gravity and such that both the planet's surface and all the divisions should be what observation showed. Now an internal spheroid or series of them confocal to the surface spheroid, the one we see, would render the latter a level surface. Saturn, therefore, must be so constituted. **So much for one half of the problem.** The next thing was to see if it also would make the divisions fall where they did.

Calculation of the attraction of such confocal spheroids for the given periods gave places for the divisions which when compared with the observed ones on the theory of partitive spin proved identical with them. The commensurable period points

fell exactly where observation placed them. The problem was solved.

Thus divisions detected in the rings told us of the internal constitution of Saturn's self. They informed us that Saturn was of the nature of an onion in partitive motion. That its different layers were rotating at different rates, the inner layers in consequence being the most oblate. So that flattened as Saturn seems when he is presented edgewise, he would offer a still more startling appearance could we see through him with the bodily eye as with the mind's eye we now do.

Now it should be noted that exceptionally good seeing alone made these discoveries possible, combined of course with long training in planetary observation. For it is upon such seeing that the future of our knowledge of the Solar System depends. Had we not been able first to detect and then to measure the minute divisions in Saturn's rings, we had never learnt the internal constitution of his mass. So with Uranus, had our air not been steady the very small inclination of the spectral lines upon which the determination of the planet's rotation-sense and period depended would have been lost in the inevitable distortions due to the grain of the plates. In fact in these investigations we are dealing with a precision so far exceeding the usual, as to open and make possible a new field of physical research.

The discoveries with regard to the rings of Saturn recorded in Memoir No. 2 of the Lowell Observatory, have an interesting application outside of themselves. For they bear testimony, if such additional evidence were needed, that the lines on Mars known as the canals are indeed as tenuous and threadlike as they are drawn at Flagstaff by all the present observers there. The testimony is as follows:

If previous drawings of Saturn, by Proctor, Barnard and others, be compared with that in the memoir, it will be seen that what has hitherto been depicted as shading in ring *B* is there shown to consist of linear circular divisions comparable for tenuity with the canals of Mars. The chief of these pencil lines were not

vergence, be due? That it was not due to any error in measurement nor to error in the data of the Saturnian system was proved by recalculation, assuming such errors to exist within any possible limits. It was not in the micrometer constant, not in Saturn's oblateness, not in Saturn's mass. Yet clearly Saturn's attraction on bodies near him needed to be increased to explain the divisions, for they were all too far out for their periods, a thing only to be accounted for by supposing a greater inward pull. But on the received idea that the planet rotated uniformly throughout, this could not be done.

To explain the discrepancies the old idea must be abandoned and some other found to take its place. It must be something, too, which not only increased his pull but increased it progressively as one neared his surface. Greater oblateness could do this, for the resulting oblateness would cause a greater attraction because a spheroid in proportion to its flattening attracts more than a sphere in the plane of its equator and increasingly so as one nears its surface from without. But superficial oblateness is barred, because we know what that is, and no allowable change is sufficient. Oblateness must be sought within. Now if the planet be supposed to consist of different layers, rotating faster inside than out, the inner ones would be more oblate than on the supposition of uniform spin. Here, then, is a clue. To follow it up is our next step.

The problem is to find an oblateness conformable internally to the laws of gravity and such that both the planet's surface and all the divisions should be what observation showed. Now an internal spheroid or series of them confocal to the surface spheroid, the one we see, would render the latter a level surface. Saturn, therefore, must be so constituted. **So much for one half of the problem.** The next thing was to see if it also would make the divisions fall where they did.

Calculation of the attraction of such confocal spheroids for the given periods gave places for the divisions which when compared with the observed ones on the theory of partitive spin proved identical with them. The commensurable period points

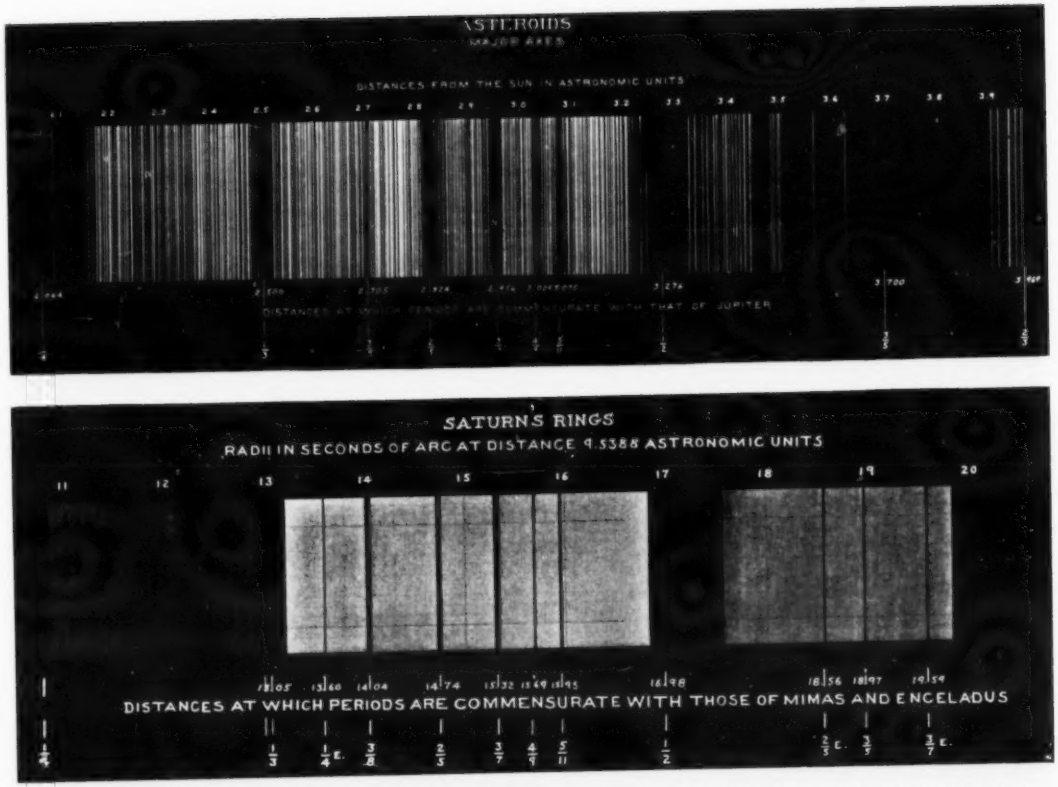
fell exactly where observation placed them. The problem was solved.

Thus divisions detected in the rings told us of the internal constitution of Saturn's self. They informed us that Saturn was of the nature of an onion in partitive motion. That its different layers were rotating at different rates, the inner layers in consequence being the most oblate. So that flattened as Saturn seems when he is presented edgewise, he would offer a still more startling appearance could we see through him with the bodily eye as with the mind's eye we now do.

Now it should be noted that exceptionally good seeing alone made these discoveries possible, combined of course with long training in planetary observation. For it is upon such seeing that the future of our knowledge of the Solar System depends. Had we not been able first to detect and then to measure the minute divisions in Saturn's rings, we had never learnt the internal constitution of his mass. So with Uranus, had our air not been steady the very small inclination of the spectral lines upon which the determination of the planet's rotation-sense and period depended would have been lost in the inevitable distortions due to the grain of the plates. In fact in these investigations we are dealing with a precision so far exceeding the usual, as to open and make possible a new field of physical research.

The discoveries with regard to the rings of Saturn recorded in Memoir No. 2 of the Lowell Observatory, have an interesting application outside of themselves. For they bear testimony, if such additional evidence were needed, that the lines on Mars known as the canals are indeed as tenuous and threadlike as they are drawn at Flagstaff by all the present observers there. The testimony is as follows:

If previous drawings of Saturn, by Proctor, Barnard and others, be compared with that in the memoir, it will be seen that what has hitherto been depicted as shading in ring *B* is there shown to consist of linear circular divisions comparable for tenuity with the canals of Mars. The chief of these pencil lines were not


ASTEROIDS
MAJOR AXES
DISTANCES FROM THE SUN IN ASTRONOMIC UNITS
2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9
DISTANCES AT WHICH PERIODS ARE COMMENSURATE WITH THAT OF JUPITER
SATURN'S RINGS
RADII IN SECONDS OF ARC AT DISTANCE 9.5388 ASTRONOMIC UNITS
11 12 13 14 15 16 17 18 19 20
18".05 13".80 14".04 14".74 15".32 15".49 15".45 16".98 18".56 18".97 19".59
DISTANCES AT WHICH PERIODS ARE COMMENSURATE WITH THOSE OF MIMAS AND ENCELADUS
1/4
1/3 1/4 E. 3/8 2/5 3/7 4/9 5/11 1/2 2/5 E. 3/5 3/7 E.

DIAGRAMS ILLUSTRATING GAPS IN THE ASTEROIDS PRODUCED BY JUPITER, AND IN THE BODIES CONSTITUTING SATURN'S RINGS PRODUCED BY HIS SATELLITES

only seen but measured by two observers with concordant results, and their positions proved explicable by celestial mechanics. Now celestial mechanics, by proving these divisions to be due to the perturbing action of Mimas, and the internal constitution of Saturn, gives us also their approximate breadth, as will be seen by comparing their striping with that of the gaps in the asteroids, major axes, caused by the analogous action of Jupiter. From this we perceive that they are in reality as pencil-like as the drawing shows. Here, then, the observers drew lines in exact keeping with fact which had been drawn elsewhere as shading.

This is in accordance with what should occur. No eye can see better than reality, though from human imperfection it may see worse. A line may be blurred into a streak, but a streak cannot be blurred into a line. The application is immediate and conclusive. Not only are the canals of Mars not streaks, but they are so fine as to have no perceptible breadth, as has been shown at Flagstaff by comparing them with the micrometer thread of .10″ diameter, which is a hawser by comparison. It is also worthy of note that no lines were seen on Saturn's self; its wisps being hazy filaments like the distant dropping of rain.

Mars.—This brings us to the third evolutionary period, a far-advanced stage of which is shown by the planet Mars. Here we are no longer dealing with invisible kernels, deep under impenetrable husks of cloud. We tread solid earth and, thanks to his advancing decrepitude, his surface, bald of hiding covering, lies patently exposed to view.

A most wonderful surface it proves to be. Over a general geography, which bears a cousinly resemblance to our own, is spread a mesh of the most geometric character, not unlike a veil of complicated design, drawn over a lady's face. To see it, though we are helped by Mars' transparent atmosphere, we are hindered by the opacity of our own.

To describe that surface more in detail is not the purpose of this article. Suffice it to say that it is sufficiently akin, yet enough unlike, our Earth's to give us by comparison illuminating views of

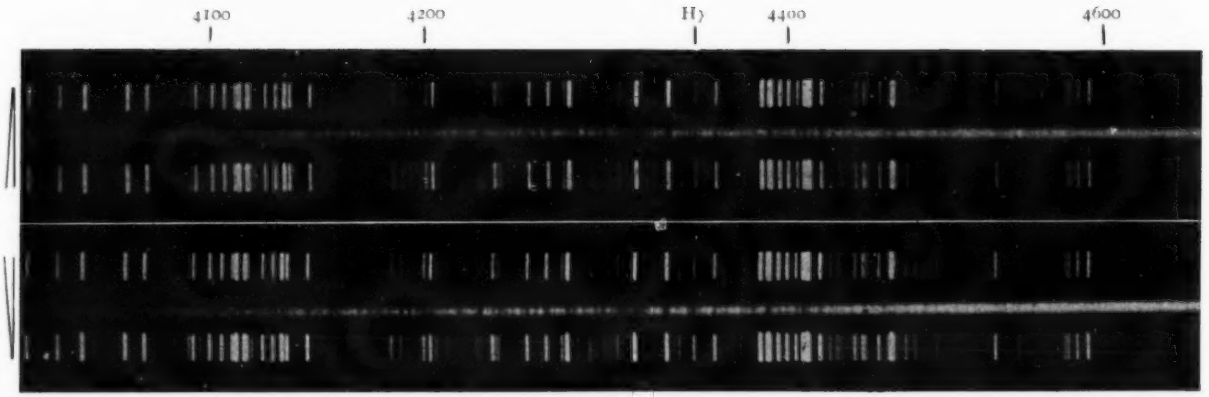
Divisions in Saturn's Rings

Compared with Commensurate Period Perturbation Points

		Computed Corresponding Distances					Observed								
			Saturn				Measures			Drawings		No. of Obs.		No. of Drawings		Remarks
	Commensurate Periods	as a sphere	as a heterogeneous spheroid rotating uniformly		as a heterogeneous spheroid of confocal layers rotating faster within; same as if homogeneous of present ellipticity		P.L.	E.C.S. Wtd. Mean		P.L.	E.C.S.	P.L.	E.C.S.	P.L.	E.C.S.	
			$a = 8''.62$ $\eta = \frac{1}{9.35}$	$a = 8''.70$ $\eta = \frac{1}{8.88}$	$a = 8''.62$ $\eta = \frac{1}{9.18}$	$a = 8''.70$ $\eta = \frac{1}{8.85}$	taking width B = 4″.00 taking width A = 2″.40 from Outer A = 40″.03									
1	2	3	4	5	6	7	8	9	10	11	12	13		14		15
		″	″	″	″	″	″	″	″	″	″					″
Mimas		26.79	26.82*		26.85			26.85		19.00	19.00			8	6	
	3/5	19.06	19.10		19.14											
	6/11	17.89	17.93		17.97							6	5			16.98
						outer	17.58	17.57	17.56	Edge						
	1/2	16.88	16.92		16.97	inner	16.86	16.87	16.89	Cassini's Division		7	2			1/5 way out in gap
										15.95	15.89			3	1	
	5/11	15.84	15.88		15.94					15.69				14		
	4/9	15.60	15.65		15.70					15.32	15.32	8		23	7	
	3/7	15.23	15.28		15.33		15.32	15.32		14.77	14.71	15	3	31	4	
	2/5	14.54	14.59		14.05		14.74	14.74	14.74	13.95	14.01	136	46	18	7	
	3/8	13.93	13.98	14.01	14.05	14.06	14.01	14.06	14.08							
						without irr.	13.21		13.21							
	1/3	12.88	12.94	12.96	13.00	with irr.	13.05	13.05	13.05			96	157			13.00
						inner est.	12.95		12.95							1/5 way out in gap
	1/4	10.63	10.70		10.78		10.85	10.83	10.80	End of ring		68	112			

* More exactly 26″.818, J being = .02893 while Struve, with rad. *Saturn* = 8″.75, $\eta = \frac{1}{9.70}$, and J = .02438, got 26″.314.

Column 4 gives the distances with *Saturn* constituted as it has hitherto been supposed to be.



SPECTRA OF URANUS SHOWING ROTATION

(By V. M. Slipher, Lowell Observatory).

The vertical lines at the left-hand end are parallel to the comparison lines, which are above and below the planet's spectrum. The inclined lines are approximately parallel to the planet's lines. They are reversed in the two photographs because the spectrograph was turned through 180° after the first one was taken. Measurement of these and other plates showed Uranus to be rotating in the direction in which its satellites revolve and in a day of $10\frac{3}{4}$ hours. Comparison lines are produced by iron and vanadium.

the general laws of cosmic physics. We learn about ourselves by studying Mars. Meteorology, physics of the globe, and other kindred sciences have already received help from this planetary neighbor and will receive more in the years to come. For every recurrent opposition of that peaceful though war-named body adds something to our store.

In conclusion, let me point out how vital to scientific advance it is that observation and theory should travel hand in hand. Without the precision afforded by the best air the recent discoveries about Uranus and Saturn would have been impossible. It was to get just such first-hand data that the observatory at Flagstaff was founded. For only the best of materials in science can stand the test of time.

TORONTO,
April 27, 1916

GREAT METEORIC STREAM OF FEBRUARY 9TH, 1913

By W. F. Denning

THIS remarkable phenomenon was fully discussed by Professor C. A. Chant and others in the JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA for 1913 and I supplied an additional note in the JOURNAL for July-August, 1915.

Feeling convinced that the meteors, as a visible swarm, were continued in a lengthy flight long after Colonel Winter's observation at Bermuda, I appealed in the *Nautical Magazine* for further observations and one important response is described in the JOURNAL, Vol. IX., p. 287-9. This carried on the observed trace of the stream to Lat. 16° 39′ N., Long. 50° 15′ W. and gave a total length of flight of nearly 4000 miles.

Further efforts to follow the course of the meteors have been partially successful and it is certain that the display was witnessed as it passed near Cape St. Roque and First-Mate W. W. Waddell, then of S.S. *Newlands*, has sent me an account of it. His ship was in Lat. 3° 20′ S., Long. 32° 30′ W., when, soon after midnight (0^h 13^m February 10), he saw during six minutes, a shoal of meteors passing from about North-West to South. I append his interesting description and there seems to be no question but that it alludes to the same event which caused such widespread interest in Canada.

Mr. Waddell's description proves that the meteors had a visible flight, when compared with the first observation from north west of Mortlach, Saskatchewan, of about 5500 miles; and this is probably only a part of the journey they performed as temporary satellites of the earth.

They were still going strongly when off Cape St. Roque and may have pursued their luminous career far southwards over

the South Atlantic Ocean, but navigators alone, during morning watches, can give us further information on the subject.

It is certain that the meteors passed southwards of Mr. Waddell's ship and that the line of their flight must be put a little southwards of that adopted by Professor Chant. This is also indicated by Mr. Porter's observation on the ship *Bellusia* before referred to.

I believe that the average height of the principal fragments of the stream was about 42 miles over a considerable part of its flight.

The phenomenon was one of so unique a character that it seems desirable to collect the data concerning it in the most exhaustive manner possible. As a final result of these enquiries I think interesting evidence may be forthcoming with regard to the places of the first and last visible presentation of the meteors.

BRISTOL, ENGLAND,
April 8, 1916.

The following is Mr. Waddell's letter :—

AT SEA, February 10, 1913.

Eight Bells, midnight.—Had just gone on bridge and Fo'castle Head, and I was just about to leave the deck for my bunk when my eye was caught by a bright shooting star in the western sky that travelled away across the heavens at a height of about twenty degrees from the horizon. As it went it seemed to drop stars for all the world like a rocket when it explodes. Each one of the stars settled a little way either above or below the parent star and followed it in parallel lines right across the heavens and disappeared in the sky to the south. I had just time to yell out to the second mate, who had relieved me on the bridge, asking if he had seen that, when a whole shower of stars of the same kind came shooting across in the wake of the first one, each of the stars wavering at the same speed and keeping regular distances from one another, all leaving a train of smaller stars in their wake that seemed to be drawn after the

parent star. The sight will ever be remembered by those who saw it.

The explosions lasted for about six minutes, during which over fifty large stars passed across the sky in straight lines and were at a height of twenty to twenty-three degrees above the horizon.

Time 0^h 13^m, Local Time, A.T.S., on February 10. Ship's position, Lat. 3° 20′ S., Long. 32° 30′ W.

(Signed). W. W. WADDELL.

S.S. *Newlands*,
of Glasgow.

ORBIT OF THE SPECTROSCOPIC BINARY BOSS 6142

By Reynold K. Young

THE binary character of Boss 6142 (α 1900 = $23^h\ 50^m{\cdot}5$, $\delta = +\ 56°\ 23'$, type *Bp*, magnitude 6·05) was announced by Adams in the *Astrophysical Journal*, April, 1912. Plates taken here indicate that the *H* and *K* lines do not shift their position with the others and remain fixed. Fifty-three spectrograms have been used in determining an orbit. On seven of these the secondary spectrum was measured. There are indications of its presence on many plates where it could not be used. On those plates where the lines due to the primary and those due to the secondary are just separating the spectral lines are very diffuse, and the spectrum is sometimes almost continuous. When the stars are moving across the line of sight the lines are fair. Table I. gives a list of all those lines which were used in reducing the measures.

Table I.

Element	Wave-Length	Element	Wave-Length
Calcium	3933·825	Hydrogen	4340·634
Calcium	3968·625	Helium	4388·100
Helium	4026·352	Helium	4471·676
Hydrogen	4101·890	Silicon	4552·750
Helium	4143·928	Silicon	4567·950

Difficulty was encountered in obtaining a period which would satisfy the observations taken on Mount Wilson. The interval covered by our own series is about four hundred and six days, while the Mount Wilson observation cover three hundred and thirty-three, and three of their observations out of four lie within a space of time of sixty-seven days. These intervals

give little latitude for adjusting the period. The first of their observations seems to be inconsistent with the others. Of course, several velocities obtained here are nearly forty kilometers in error and it may be that the residual of sixty-eight kilometers in the first observation taken on Mount Wilson is accidental and does not indicate any departure from elliptic motion. Dr. Adams reports that the spectrum is certainly composite on the plate taken November 1st, and that the settings were made on the most intense parts of the absorption lines. A remeasure of this plate yielded practically the same result as published.

The period finally adopted was 13·435 days and then the observations were grouped into normals, preliminary elements obtained and corrected in the usual manner. The observations and final elements follow.

TABLE II.

MOUNT WILSON OBSERVATIONS OF BOSS 6142

Date	Julian Date	Phase from J.D. 2,420,800	Velocity	O-C
1911 Nov. 1	2,419,342·758	7·03	- 53	+ 68
1912 Jan. 6	9,406·662	3·76	- 11	- 26
1912 Jan. 9	9,409·633	6·73	-133	- 15
1912 Sept. 30	9,675·811	4·21	- 23	- 13

TABLE III.—OTTAWA OBSERVATIONS OF BOSS 6142

Plate	Obs.*	Date	Julian Date	Phase from J.D. 2429800	Velocity Primary	Wt.	Vel. from H and K	O − C	Vel. Secondary
		1915							
6747	H	Jan. 28	2,420,526·535	8·67	− 133	1	− 16	− 4	+ 105
6756	C	" 29	527·528	9·66	− 120	1	− 23	− 9	
6766	C	Feb. 3	532·599	1·30	+ 81	1	− 38	− 19	
6773	H	" 4	533·541	2·24	+ 104	1		+ 19	
7077	Y	June 27	676·720	11·07	− 39	½		+ 12	
7085	H-Y	July 1	680·742	1·66	+ 108	1		+ 11	− 189
7093	C	" 9	688·699	9·61	− 93	¼		+ 19	
7103	C	" 14	693·818	1·30			− 24		
7113	Y-H	" 20	699·745	7·22	− 108	1		+ 4	
7116	Y	" 22	701·754	9·23	− 126	1	− 21	− 5	
7125	C	" 26	705·833	13·31	+ 59	½	− 21	− 9	
7128	Y-H	" 27	706·726	0·77	+ 93	1	− 30	− 3	− 155
7130	C	" 28	707·824	1·87	+ 95	1	− 29	+ 2	
7137	Y	Aug. 1	711·764	5·81	− 75	1	− 22	+ 11	
7141	Y	" 5	715·772	9·82	− 104	1	− 40	+ 1	
7148	Y	" 10	720·677	1·29	+ 102	1	− 28	+ 2	− 168
7157	Y	" 14	724·764	5·37	− 35	1		+ 32	
7159	Y	" 17	727·677	8·29	− 124	1		+ 8	+ 170
7160	Y	" 17	727·820	8·43	− 130	1	− 30	0	+ 133
7170	Y	" 26	736·650	3·82	− 16	1	− 18	− 28	
7171	Y	" 26	736·706	3·88	− 19	1	− 2	− 28	
7188	P″	Sept. 1	742·694	9·87	− 106	½		− 2	
7222	H	" 9	750·687	4·43	− 34	1		− 15	
7237	Y	" 11	752·765	6·50	− 120	½	− 30	− 11	
7262	C-P″	" 17	758·747	12·49	− 13	1		− 41	
7269	Y	" 19	760·663	0·97	+ 102	1	− 33	+ 4	− 165
7275	Y	" 21	762·670	2·97	+ 56	1	− 26	− 3	
7292	Y	" 28	769·547	9·85	− 105	½		− 1	
7301	Y	" 29	770·611	10·92	− 39	1	− 24	+ 20	
7309	H	" 30	771·563	11·87	− 38	1		− 30	
7318	Y	Oct. 3	774·555	1·42	+ 99	1		0	− 197
7328	Y	" 10	781·601	8·47	− 132	1	− 20	− 1	
7329	Y	" 10	781·672	8·54	− 147	1		− 17	
7341	Y	" 15	786·534	13·40	+ 100	1	− 17	+ 29	− 141
7343	Y	" 15	786·660	0·10	+ 71	½		− 6	
7356	Y	" 21	792·525	5·96	− 80	1		+ 11	
7370	Y-H	" 28	799·753	13·19	+ 47	¼	− 26	− 12	
7405	Y	Nov. 13	815·697	2·26	+ 86	1	− 19	+ 2	
7410	Y	" 16	818·514	5·08	− 49	1		+ 3	
7411	Y	" 16	818·597	5·16	− 46	1	− 20	+ 10	
7413	C	" 17	819·500	6·07	− 118	1	− 25	− 23	
7426	Y	" 24	826·526	13·09	+ 41	¼		− 17	
7436	P	Dec. 1	833·505	6·72	− 119	½	− 28	− 4	
7456	Y	" 28	860·482	6·74	− 76	¼		+ 39	
		1916							
7473	H	Jan. 6	869·506	2·33	+ 57	1		− 26	
7484	Y	" 14	877·483	10·31	− 110	1	− 20	− 23	
7485	Y	" 14	877·531	10·36	− 67	¼		+ 17	
7489	C	" 17	880·531	13·36	+ 73	½		+ 3	
7491	Y	" 23	886·515	5·91	− 68	1	− 19	+ 22	
7493	Y	" 28	891·518	10·91	− 74	1	− 23	− 14	
7499	P	" 29	892·507	11·90	− 19	1		− 13	
7503	Y	Feb. 10	904·521	10·48	− 56	½	− 3	+ 23	
7541	H	Mar. 9	932·514	11·60	− 23	1		0	

*H = Harper. C = Cannon. P = J. S. Plaskett. P″ = H. Plaskett. Y = Young.

FINAL ELEMENTS

$P = 13{\cdot}435$ days

$T = \text{J.D. } 2{,}420{,}800\,634 \pm 0{\cdot}271$ days.

$e = 0{\cdot}105 \pm 0{\cdot}013$

$\omega = 339°{\cdot}56 \pm 7°{\cdot}1$

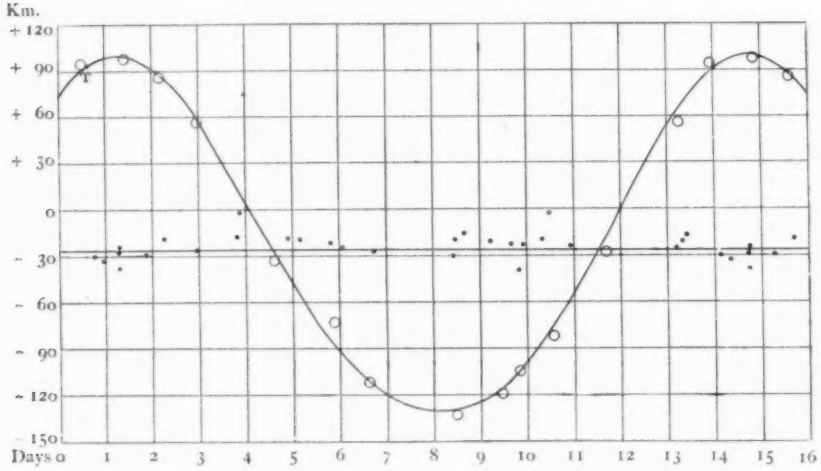
$K = 115{\cdot}5$ km. $\pm 1{\cdot}33$ km.

$\gamma = -26{\cdot}7$ km. $\pm 0{\cdot}90$ km.

$a \sin i = 21{,}200{,}000.$ km.

$$\frac{m^3 \sin^3 i}{(m+m_1)^2} = 2{\cdot}11 \times \text{sun.}$$

The residuals which these elements give for the individual observations are shown in the tables of observations under the heading O–C. The probable error of an average plate is eleven kilometers.



RADIAL VELOCITY CURVE OF BOSS 6142

SECONDARY SPECTRUM

The above elements rest entirely on measures of the primary. The measures of the secondary were grouped into two normal places as follows :—

Phase	Velocity	Weight	O-C
2·03	- 169	5	0
8·46	+ 136	3	0

A value of K_1' was determined which would best harmonize these with the elements of the primary. It was possible to adjust the value of K_1' so as to leave no residuals, but, nevertheless, we must regard the value of the amplitude of the secondary given as only roughly approximate. We have the following additional elements :—

$$K_1' = 167 \text{ km.}$$
$$K' : K_1' = 1 : 1{\cdot}45$$
$$a_1 \sin i = 30{\cdot}700{,}000 \text{ km.}$$
$$m \sin i = 18{\cdot}5 \times \text{sun}$$
$$m_1 \sin i = 12{\cdot}7 \times \text{sun.}$$

H AND *K* LINES

The phenomenon that these lines in this star present is quite similar to that presented in several other stars of this type. There seems to be no evidence of variation in their position. On many plates the spectrum is too faint to show *H* and *K*, and on others the measurement of the *H* line is interfered with by the presence of H_ϵ but in general the lines are narrow and sharp in striking contrast to the other lines of the star. Regarding their position as fixed, they yield a velocity − 24·0 km. ± 4·9 km.

DOMINION OBSERVATORY,
OTTAWA, CANADA.

LOCATION OF EPICENTRES FOR 1914 AND 1915

By Otto Kloiz

IN the May-June number of the JOURNAL for 1915, the location of epicentres for the first half of 1914 was given, and the reason for the omission of the latter half of that year was explained,— lack of data from important European stations due to the present lamentable war. Since then some data have reached us, some by loan from the Harvard station, so that we were able to continue the determination and bring our series begun in 1911 up to date, *i. e.*, up to the end of 1915. It may be repeated, what was said in the previous report, that the extent of America is great enough to make us, if necessary, independent of the rest of the world for triangulating earthquakes, that is, determining the epicentre of any decent earthquake, a tectonic quake, a quake that shakes the world, provided we have seismologica stations judiciously distributed over the continent, including the Hawaiian possessions of the United States, and each station provided with modern, sensitive seismographs, as well as with efficient time, time correct to the individual second, an accuracy that is now readily attainable through the Arlington wireless signals, if not otherwise provided for as it is by stations supplied with transit instruments.

We must look to the United States for co-operation in attaining this very desirable end. Of all the various branches of geophysics there is no one which offers us a better opportunity for studying the interior of the earth with all its cognate problems, and in which man is so vitally interested, than does the new science of seismology.

During the 18 months referred to, 114 earthquakes were recorded here, but not all gave the phases P, S, L, yet all these quakes were considered in the location of epicentres, utilizing the

other data available. Of all the data at hand there were 68 of the 114 quakes available for plotting. Of this number the intersection of the circles failed to give a definite point for 9 of these and they are accordingly given with the remark "No location." Four others gave more than one point, each of which might be the epicentre. The selection of the epicentral point given was due to its position in a seismic area. These 4 earthquakes have the remark "Location doubtful."

In the following table, column 1 gives the date of the quake; column 2 gives the stations utilized for plotting; column 3 then gives the geographic co ordinates of the epicentre resulting from such plotting. In case the intersections are unsatisfactory and far apart, due, of course, to erroneous interpretation of some or all of the seismograms considered, then "No location" is entered; column 4 gives the epicentre as found in the reports received; while column 5 gives the available data for computing or plotting the epicentre. When a distance in this column is given with brackets, it indicates that the respective station considered such distance doubtful.

The locations have all been made by the stereographic method, for which our published tables — an extended edition was recently issued — for facilitating the plotting, have been utilized.

The plotting has all been done by Mr. E. A. Hodgson, M.A., of our office.

LOCATION OF EPICENTRES FOR 1914·15

Date	Stations	Epicentre	Locations	Other Data
1914 July 4-5	No Location			Ottawa = 2000 Graz = (9000) Pulkowa = 10050 Pulkowa = 10910 Pola = 5000 Batavia = 370 Trieste = (5800) Harvard = (1960) Sydney = 3500 Tiflis = 8960 Osaka = 2810
July 5	No Location			Pola = 7600 Pulkowa = 10460 Sydney = 3500 Trieste = (8900) Tiflis = 9550
July 6	Czernowitz = 8300 Aachen = 8700 Cartuja = 11020 Pulkowa = 7630 Pulkowa = 7870 Trieste = 9100 Göttingen = 9200 Tiflis = 7160 Osaka = 2020	ϕ = 22°·5 N. λ = 120° E.	Pulkowa ϕ = 26°·3 N. λ = 122°·5 E. and ϕ = 24°·4 N. λ = 123°·8 E.	Ottawa = 1800 Taihoku-Formosa reports the quake to be 124 km. distant.
July 8	No Location		Tiflis ϕ = 9° S. λ = 98° 5 E.	Ottawa = 5200 Batavia = (270) La Paz = 4200
July 14	Aachen = (10500) Batavia = 430 Tiflis = 7850	ϕ = 3° S. λ = 104° E.	Tiflis ϕ = 46°·7 N. λ = 173°·7 E.	Ottawa = (7300) Harvard = (6350)
July 17	Ottawa = 6800 Aachen = 8600 Tiflis = 8960 Paris = 8850	ϕ = 51°·5 N. λ = 176°·3W.		Harvard = 6300+ Osaka = 5250
July 21	Ottawa = 3970 St. Louis = (4350) Harvard = 4280 Göttingen = 8300 Tiflis = 9440 Tiflis = 9870	ϕ = 48°·2 N. λ = 128°·1 W.		
Aug. 3	St. Louis = 2800 Harvard = 2770 Pulkowa = 9370	ϕ = 20° N. λ = 83°·6 W.		Ottawa = 2540 La Paz = 6440 Hamburg = 8060

Location of Epicentres for 1914-15

Date	Stations	Epicentre	Locations	Other Data
1914				
Aug. 4	Ottawa = 9560 Zi-Ka-Wei = 2500 Barcelona = 6760 Cartuja = 7820 Göttingen = (5900) Tiflis = 5830 Athens = 5710 Paris = 11900 Osaka = 4500 Algiers = 7500 Hamburg = 5920 Konigstuhl = (6530)	ϕ = 45°·8 N. λ = 94° 15′ E.	Tiflis ϕ = 42°·7 N. λ = 91°·9 E.	Harvard = (2770)
Aug. 8	Ottawa = 4100 Santa Clara = 803 St. Louis = 2825 Harvard = 4500	ϕ = 32°·4 N. λ = 121° 37′ W.		
Aug 22	Ottawa = 3900 St. Louis = 3500 Harvard = 4540 Guildford = 2800 Paris = 8600 Algiers = 9500 Hamburg = 8500	ϕ = 45°·9 N. λ = 129°·3 W.		Göttingen = 8700
Aug. 22	No Location			Cartuja = 9050 Göttingen = (17000) Sydney = 2400
Sept. 25	Ottawa = 5440 Cartuja = 9000 La Paz = 1830	ϕ = 3°·8 S. λ = 78°·9 W.	Press report gives Ecuador.	
Oct. 1	Ottawa = 4200 La Paz = 2550 Harvard = 3980 Guildford = 7965	ϕ = 6°·5 N. λ = 69°·6 W.		Batavia = (4500) Cartuja = 7530
Oct. 3	Barcelona = 6500 Cartuja = 5940 Cartuja = 5900 St. Louis = 3700 La Paz = 3500 Athens = 8350 Paris = 6600 Osaka 12910 Hamburg = 7350 Strassburg = (7070)	= 13°·4 N. λ = 57°·7 W.	Cartuja ϕ = 12° N. λ = 56° W. and also ϕ = 13°·4 N. λ = 57°·7 W.	Ottawa = 3420 Harvard = 2860 Göttingen = 6600 Guildford = 5775 Tiflis = 9320 Santa Clara = 2393 Algiers = 6600

LOCATION OF EPICENTRES FOR 1914-15

Date	Stations	Epicentre	Locations	Other Data
1914 Oct. 3	Ottawa = 8200 Barcelona = 2570 Cartuja = 2900 St. Louis = 9000 Harvard = 8625 La Paz = 12400 Gottingen = 2200 Guildford = 3110 Tiflis = (1260) Athens = 570 Batavia = 9500 Osaka = 9000 Algiers = 2500 Hamburg = 2370 Strassburg = (2230) Königstuhl = 2180	ϕ = 37° N. λ = 29°·2 E.	Press report gives Smyrna Cartuja ϕ = 36°·6 N. λ = 30°·2 E.	
Oct. 22	Ottawa = 1780 St. Louis = 2500 Washington = (1400)	ϕ = 29°·3 N. λ = 65°·2 W.		
Oct. 23	Ottawa = 6300 Harvard = 5900 Washington = (5920) Tiflis = 9030 Algiers = 6000	ϕ = 0°·5 S. λ = 37°·5 W. Location Doubtful		Cartuja = 11100 Batavia = 520 Osaka = 2880 Hamburg = 9820 Strassburg = 11450
Nov. 10	Ottawa = 900 Washington = 600	ϕ = 38° N. λ = 70° W. Location Doubtful		
Nov. 18	No Location			Ottawa = 5030 Harvard = (5000) Washington = 4175 Cartuja = 9210 Tiflis = 8640
Nov. 24	Cartuja = 11030 Batavia = 4500 Hamburg = 9050	ϕ = 28°·7 N. λ = 126°·6 E.	Cartuja ϕ = 28°·7 N. λ = 126°·6 E. Tiflis ϕ = 34°·3 N. λ = 149°·2 E	Ottawa = 4030 Barcelona = 6550 Harvard = 3980 Guildford = 8700 Guildford = 8855 Washington = 3640 Tiflis = 8600 Athens = 9250 Osaka = 1730 Algiers = 7600 Konigstuhl = 3050

Location of Epicentres for 1914-15

Date	Stations	Epicentre	Locations	Other Data
1914 Dec. 20	No Location			Ottawa = 9200 Harvard = 6550 Washington = (8000) Cartuja = 9680 Cartuja = 9750 Osaka = 7940 Algiers = (6800)
Dec. 25	Ottawa = 2800 Harvard = 2490 Washington = 2160	ϕ = 20°·2 N. λ = 71°·5 W.		
1915 Jan. 5	Eskdalemuir = 9300 Tiflis = 6990 Zi-Ka-Wei = 780 Athens = 8850 Osaka = 1750	ϕ = 24°·9 N. λ = 120°·5 E.	Tiflis ϕ = 9° 50′ N. λ = 107° 2′ E. Cartuja ϕ = 19°·7 N λ = 94°·8 E.	Ottawa = 4220 Harvard = 3950 Washington = (1800) Batavia = 2800 Cartuja = 9400 Cartuja = 11100 Algiers = (5300) Königstuhl = 2920 Strassburg = 11500
Jan. 13	Ottawa = 6860 Barcelona = 940 Harvard = 6750 Eskdalemuir = 1930 St. Louis = 6600 Cartuja = 1600 Tiflis = 2610 Zi-Ka-Wei = 9440 Athens = 890 Osaka = 9490 Algiers = 1100 Strassburg = 940	ϕ = 42°·1 N. λ = 13°·5 E.	Italian Quake at Avezzano	
Feb. 25	Ottawa = 9150 Eskdalemuir = 8000 Strassburg = 8600	ϕ = 51° N. λ = 158°·6 E.	Eskdalemuir ϕ = 53° N. λ = 177° E.	Harvard = 9200 Barcelona = (8510) St. Louis = (8000) Batavia = 7500 Athens = 270 Osaka = 7530 Cartuja = 9410 Algiers = (8700)
Feb. 28	Ottawa = 13000+ Eskdalemuir = (10000) Batavia = 2700 Osaka = 1880 Strassburg = 9500	ϕ = 17° N. λ = 113°·5 E.	Tiflis ϕ = 39° N. λ = 137° E.	Tiflis = 7380 Cartuja = 10300 Königstuhl = 7910

Location of Epicentres for 1914-15

Date	Stations	Epicentre	Location	Other Data
1915 Mar. 12	Zi-Ka-Wei = 2000 Batavia = 3300 Osaka = 3340 Strassburg = 8500	ϕ = 23°·2 N. λ = 103°·3 E		Tiflis = 8410
Mar. 17	Ottawa = 9050 Tiflis = 7410 Barcelona = 9100 Eskdalemuir = 8450 Zi-Ka-Wei = 2150 Batavia = 6000 Osaka = 970 Cartuja = 10050 Algiers = 9200 Strassburg = 8200	ϕ = 43° 4 N. λ = 140°·9 E.	Tiflis ϕ = 60°·2 N. λ = 163°·9 E. Eskdalemuir ϕ = 40° N. λ = 129° E.	
Apr. 7	Ottawa = 4440 Harvard = 4300	ϕ = 5°·5 N. λ = 85° W.	La Paz gives Arequipa	
Apr. 23	Ottawa = 5000 Barcelona = 8140 Cartuja = 7810 Eskdalemuir = (8360) Harvard = 4670 St. Louis = 4450	ϕ = 1° 3 N. λ = 71° W.	Cartuja ϕ = 5°·5 S. λ = 69°·5 W. Eskdalemuir ϕ = 6° S. λ = 56° W. La Paz gives Arequipa	Athens = 2010
Apr. 28	No Location			Tiflis = 4020 Cartuja = 5400 Zi-Ka-Wei = 2300
May 1	Ottawa = 8420 Tiflis = 8130 Victoria = 4550 Victoria = 4800 Barcelona = 9600 Eskdalemuir = 8420 Harvard = 8980 Zi-Ka-Wei = 3200 St. Louis = 8300 St. Boniface = 8361 Santa Clara = 5096 Batavia = 7750 Athens = 9210 Osaka = 2460 Algiers = 10000 Strassburg = 8400 Königshstuhl = 7030	ϕ = 49° N. λ = 155°·9 E.	Sydney ϕ = 47° N. λ = 165° E. Tiflis ϕ = 43°·2 N. λ = 152°·5 E. Eskdalemuir ϕ = 47° N. λ = 153° E. Harvard gives Kurile Ids. as the Epicentre Zi-Ka-Wei ϕ = 46° N. λ = 153° E.	Sydney = 9100

Location of Epicentres for 1914-15

Date	Stations	Epicentre	Location	Other Data
1915				
May 2	Ottawa = 9280 Tiflis = 8090 Eskdalemuir = 8650	ϕ = 43° N. λ = 150°·4 E		Osaka = 5690 Strassburg = 8000
May 3	Ottawa = 8640 Tiflis = 8030 Cartuja = 9820 Eskdalemuir = 8380 Athens = 9200 Strassburg = 8400	ϕ = 47°·5 N. λ = 152°·8 E.		Osaka = 3530
May 5	Osaka = 4980 Sydney = 2400 Batavia = (4500)	ϕ = 10°·7 S. λ = 147°·8 E.		Ottawa = (8000) Tiflis = (9460) Eskdalemuir = (8760) Harvard = (8730)
May 6	Ottawa = 3960 Eskdalemuir = 8240 St. Louis = 3300	ϕ = 10° N. λ = 80° W.	Cartuja ϕ = 39° 8 N. λ = 123°·4 W. or ϕ = 16°·8 N. λ = 100°·4 W.	Cartuja = 9510 Harvard = 4820 St. Boniface = 3150 Santa Clara = 7485 Strassburg = 8600
May 8	Tiflis = 7240 Eskdalemuir = (9300) Cartuja = 8020 Strassburg = 8000	ϕ = 22° S. λ = 38° E.		
May 12	Ottawa = (6500) Tiflis = 8220 Barcelona = (3900) Eskdalemuir = 6240 Harvard = 6075 Athens = 6300 Cartuja = (4720) Algiers = (4500) Strassburg = 5700 Königstuhl = 6740	ϕ = 3°·5 N. λ = 22°·7 W.		
May 21	Eskdalemuir = 6350 Athens = 3600 Cartuja = 4800	ϕ = 5° N. λ = 29°·5 E.		Ottawa = (7000) Harvard = (8800) Batavia = 8200 Königstuhl = 7610
June 1	Ottawa = 4860 Tiflis = 1710 Barcelona = (4010) Cartuja = 4770 Eskdalemuir = (2800) Harvard = 5100	ϕ = 80° N. λ = 4°·9 E.		Toronto = (3450) St Louis = 4800 Algiers = (3700)

LOCATION OF EPICENTRES FOR 1914-15

Date	Stations	Epicentre	Locations	Other Data
1915				
June 1	Zi-Ka-Wei = 5120 Athens = 4760 Osaka = 7160 Strassburg = (3530			
June 4	Tiflis = 8070 Eskdalemuir = 8770 Zi-Ka-Wei = 2400 Osaka = 870	ϕ = 39°·5 N. λ = 146° 6 E		
June 6	Ottawa = 6940 Cartuja = 9050 Harvard = 6540	ϕ = 16°·6 S. λ = 68°·6 W.	Cartuja ϕ = 16°·6 S. λ = 68°·6 W. Eskdalemuir ϕ = 11° S. λ = 58° W. La Paz ϕ = 20° S. λ = 69°·5 W.	Barcelona = 9100 Eskdalemuir = 8970 Zi-Ka-Wei = 3000 St. Louis = 5800 Algiers = 9000 Strassburg = 9300 La Paz = 370
June 22	Ottawa = 7210 La Paz = 400 Harvard = 6790 Algiers = 9600	ϕ = 19°·3 S. λ = 68° 9' W.	La Paz gives Chile, as the Epicentre	Eskdalemuir = 9280 Zi-Ka-Wei = 3100
June 23	Ottawa = 3700 Santa Clara = 881 Harvard = 4110	ϕ = 32° 45' N. λ = 115° 30' W	Imperial Valley, Cal.	
June 23	Ottawa = 3700 St. Louis = 2450 Santa Clara = 801 Harvard = 3850	ϕ = 32° 45' N λ = 115° 30' W	Imperial Valley, Cal.	
July 31	Ottawa = 7700 Barcelona = 9200 Zi-Ka-Wei = 4050 Santa Clara = 5525 Athens = 8350 Osaka = 3620 Naples = 8800 Cartuja = 9780 St. Louis = 7600 Honolulu = 4340 Algiers = 9600 Strassburg = 8440	ϕ = 54°·3 N. λ = 161° 3 E.		
Aug. 3	Sydney = 3500 Zi-Ka-Wei = 3900 Harvard = 14900	Φ = 5° S. λ = 138° E.	Sydney Φ = 5° S. λ = 138° E.	Ottawa = 3240 Eskdalemuir = 8540 Algiers = (9900)

Location of Epicentres for 1914-15

Date	Stations	Epicentre	Location	Other Data
1915				
Aug. 6	Ottawa = 9150 Zi-Ka-Wei = 2800 Osaka = 1780 Harvard = 9000	ϕ = 49°·3 N. λ = 144°·9 E	Eskdalemuir ϕ = 42° N. λ = 143° E.	Barcelona = 10010 Eskdalemuir = 8790 Cartuja = 11100 Algiers = 9900
Aug. 7	Ottawa = 5600 Barcelona = 1500 Eskdalemuir = 2540 Athens = 300 Naples = 430 Cartuja = 2150 Königstuhl = 1420	ϕ = 39°·3 N. λ = 19°·3 E.	Eskdalemuir ϕ = 39° N. λ = 22° E.	Osaka = 10780
Aug. 16	Eskdalemuir = (8220) Osaka = 4520 Cartuja = 9450 Strassburg = 8920	ϕ = 52° N. λ = 179° W.	Eskdalemuir ϕ = 51° N. λ = 177° E.	Ottawa = (3500)
Sept. 6	Zi-Ka-Wei = 9100 Sydney = 4000	ϕ = 20° S. λ = 171° W. Location Doubtful		Victoria = 10310 Cartuja = 11150 Harvard = (10300)
Sept. 7	Ottawa = 3750 Washington = 3040 La Paz = 4200 Berkeley = 4050 Santa Clara = 3596 Eskdalemuir = 8270 Victoria = 4770 Toronto = 3500 Barcelona = 9080 Cartuja = 8630 St. Louis = 3200 Harvard = 3580 Algiers = 9200 Königstuhl = 9400	ϕ = 12°·8 N. λ = 86°·5 W.	Eskdalemuir ϕ = 13° N. λ = 84° W.	Athen = 2590
Sept. 7	Ottawa = (3750) La Paz = (4200) Harvard = 3610	ϕ = 14°·1 N. λ = 90° 5 W.		Victoria = (6440)
Sept. 7	Ottawa = (3750) La Paz = 3900 Harvard = 3040	ϕ = 15° N. λ = 71°·1 W.		
Sept. 12	Ottawa = 5530 Eskdalemuir = 6110 Barcelona = 5490	ϕ = 7°·5 N. λ = 37°·7 W.		

LOCATION OF EPICENTRES FOR 1914-15

Date	Stations	Epicentre	Locations	Other Data
1915 Sept. 12	Cartuja = 4550 La Paz = 4280 Algiers = 5290			
Oct. 3	Santa Clara = 503 Cartuja = 9000	φ = 41° N. λ = 118°·1 W. Exact Location Doubtful		Harvard = 2600 Victoria = 220
Oct. 3	Ottawa = 3330 Berkeley = 570 Osaka = 7690 Victoria = 1300 Toronto = 3164 Barcelona = 9240 St. Louis = 2300 Cartuja = 9210 Algiers = 9500	φ = 40°·2 N. λ = 118°·5 W.	Utah-Idaho quake	
Oct. 11	La Paz = 3450 Cartuja = 6460 Eskdalemuir = 6760	φ = 15°·1 N. λ = 64°·9 W.	Eskdalemuir φ = 17° N. λ = 65° 5 W.	Ottawa = 2140 Algiers = 5000
Oct. 11	Ottawa = 5430 La Paz = 4330 Cartuja = 4660 Eskdalemuir = 5900	φ = 9° N. λ = 38° W.		
Nov. 1	Ottawa = 9340 Osaka = 800 Victoria = 7280 Eskdalemuir = 9000 Harvard = 9590 Cartuja = 11000	φ = 38°·7 N. λ = 145°·5 E.	Osaka φ = 38°·5 N. λ = 142° E. Eskdalemuir φ = 41° N. λ = 149° E. Cartuja φ = 38°·7 N. λ = 145°·5 E.	Toronto = 11760 St. Louis = 3200 Algiers = 5900
Nov. 21	Ottawa = 3520 St. Louis = 2500 Harvard = 3900 Cartuja = 9660	φ = 41°·7 N. λ = 119° W.		Victoria = 1940 Victoria = 2070
Dec. 3	No Location			Ottawa = 7500 Victoria = 2040 Algiers = 2800
Dec. 7	Ottawa = 5340 La Paz = 4190 Algiers = 5300	φ = 8° N. λ = 40°·5 W.		

1915 Dec. 12	No Location			Ottawa = 3240 St. Louis = 1600 La Paz = 4700 Harvard = 4000
Dec. 28	No Location			Ottawa = 3800 La Paz = 520 Algiers = 9300
Dec. 31	Ottawa = 4000 Victoria = 830 Harvard = 4810	$\varphi = 40^\circ 45'$ N. $\lambda = 124^\circ$ W.	Victoria gives Eureka, Cal.	St. Louis = 6300
Dec. 31	No Location			Ottawa = 3200 La Paz = 5870 Victoria = 1160 Sydney = 2820 Sydney = 2720

DOMINION OBSERVATORY,
OTTAWA, CANADA
April 19, 1916.

MAGNETIC RESULTS 1915

By Otto Klotz

DURING the nine seasons that the Observatory has prosecuted the magnetic survey of Canada, there have been occupied some 400 stations across the continent from Cape Sablon and Sydney on the Atlantic, to Nanaimo and Prince Rupert on the Pacific. The stations average from 25 to 30 miles apart. A number of stations have been selected as repeat stations for the determination of the annual change. Possibly next year only repeat stations will be occupied across the continent in order that we can publish magnetic data and maps reduced to a uniform epoch and based on our own material.

Very nearly all the observations have been made by Mr. C. A. French, of the Observatory, and with the same instruments, assuring thereby in a large measure homogeneity in the work. The following is his account of the past season's work :

During the season of 1915, forty-eight stations were occupied, besides a second station at Sicamous, and spring and fall observations at the observing hut in Ottawa and the standardizing observatory at Agincourt.

The instruments used were the Tesdorpf magnetometer, No. 1977, for the determination of declination and horizontal intensity ; Dover dip circle, No. 145, for inclination or dip ; and a Watt transit for azimuth and time. The half seconds mean time chronometer, Bond No. 511, was used for determining the time of an oscillation of the intensity magnet as well as for recording time for other observations.

From comparison observations for the standardization of the instruments at Agincourt it was found that :

(1) the observed declination with Tesdorpf No. 1977 requires a correction of + 3′·6 to reduce it to the standard, that is

the westerly declination, which is considered $-ve$, must be decreased by that amount and the easterly declination, which is considered $+ve$, must be increased.

(2) the observed horizontal intensity requires a correction of $-\cdot00258H$ to reduce it to the standard, where H is the observed horizontal intensity.

The standard instrument for inclination since 1912 has been the Toepfer earth inductor No. 1911. The correction for the season of 1915, to the Dover dip circle No. 145 on standard was 0'·7. This correction, as well as the corrections determined at Agincourt, is the mean of spring and fall comparisons.

At each station the eastern and western elongations were observed and the mean taken as the adopted value of declination for the day. The adopted values, both for inclination and horizontal intensity, were determined from two observations, one in the forenoon and one in the afternoon. The results given in the table of Magnetic Results are, with few exceptions, the results of two days' observing, that is two eastern and two western elongations, four inclinations and four determinations of horizontal intensity.

A few of the stations were previously occupied, thus furnishing some secular variation data, which are given in the table of Annual Change.

INTERCOMPARISONS OF MAGMETIC INSTRUMENTS

After completing the field work of 1915, as well as the standardizing observations at Agincourt and the observing at Ottawa on return from the field, an opportunity was afforded of making a series of comparisons between the Dominion Observatory magnetic instruments and the standard instruments of the Carnegie Institution, Washington, D.C. A magnetometer and earth inductor from the Agincourt magnetic observatory were also compared. Some of the chief results are given below in the Summary of Intercomparisons. Some previous results are also given.

The designations used in the summary are as follows :—

Ag. S. = Agincourt Magnetic Standard, which has been adopted as the standard for the Dominion Observatory work.

I. M. S. = International Magnetic Standard.

M. S. 15 = Meteorological Service magnetometer No. 15.

M. S. 89 = Meteorological Service earth inductor No. 89 by Toepfer and Sons.

D. O. 1977 = Dominion Observatory magnetometer No. 1977 by Tesdorpf.

D. O. 15 = Dominion Observatory magnetometer No. 15 by Cooke and Sons.

D. O. 1911 = Dominion Observatory earth inductor No. 1911 by Toepfer.

SUMMARY OF RESULTS OF INTERCOMPARISONS OF MAGNETIC INSTRUMENTS

A.—Declination

(1) I. M. S.–M. S. 15 = + 0′·1 Determined at Washington, 1910. See II. Volume, Researches Dep't Terrestrial Mag., p. 215.

(2) I. M. S. – M. S. 15 = – 0′·9 Determined at Washington, November and December, 1915.

(3) I. M. S. – Ag. S. = – 1′·1 Determined at Agincourt, 1906, 1909, 1910. See II. Vol., Res. Dep. Terr. Mag., p. 216.

(4) Ag. S. – M. S. 15 = + 1′·4 Results supplied by Mr. Jackson, of the Meteorological Service.

(5) Ag. S. – D. O. 1977 = + 3′·4 Determined at Agincourt, October, 1915.

(6) I. M. S. – D. O. 1977 = + 1′·5 Determined at Washington, November and December, 1915.

(7) I. M. S. – D. O. 15 = – 0′·3 Determined at Washington, November and December, 1915.

(8) D. O. 1977 – D. O. 15 = – 3′·8 Determined at Ottawa, April, 1915.

(9) D. O. 1977 – D. O. 15 = – 2′·8 Determined at Ottawa, November, 1915.

(10) D. O. 1977 – D. O. 15 = – 2′·3 Determined at Ottawa, March, 1916.

(11) Ag. S. – D. O 15 = + 0′·8 Determined at Agincourt, January, 1912.

Therefore

(12) I.M.S.–Ag.S. = –2′·3 From (2) and (4). Compare with (3)

(13) I M.S.–Ag S. = –1′·3 " (1) and (4). " " "

(14) I.M.S.–Ag. S. = –1′·9 " (5) and (6). " " "

(15) I.M.S.–Ag.S. = –1′·1 " (7) and (11). " " "

(16) D.O. 1977–D.O. 15 = –1′·8 From (6) and (7). Compare with (8), (9) and (10).

B.—Horizontal Intensity

(1) I.M S. – D.O. 1977 = – ·00253*H* Determined at Washington November and December, 1915.

(2) Ag.S. – D.O. 1977 = – ·00258*H* Determined at Agincourt, April and November, 1915.

Therefore

(3) I.M.S. – Ag.S. = + ·00005*H* From (1) and (2).

(4) I.M.S. – M.S. 15 = + ·00007*H* Determined at Washington, November and December, 1915.

(5) I.M.S. – M.S. 15 = + ·00035*H* Determined at Washington, February and March, 1910. See II. Vol., Res. Dep. Terr. Mag., p. 215.

(6) I.M.S. – Ag.S. = + ·00008*H* See II. Vol., Res. Dep. Terr. Mag., p. 216. Compare with (3).

(7) I.M.S. – D.O. 15 = + ·00106*H* Determined at Washington, November and December, 1915.

C.—Inclination

(1) I.M.S. – M.S. 89 = + 0′·8 Determined 1910–1912. See II. Vol., Res. Dep. Terr. Mag., p. 216.

(2) I.M.S. – M.S. 89 = – 0′·15 Determined at Washington, November and December, 1915.

(3) I.M.S. – D.O. 1911 = – 0′·25 Determined at Washington, November and December, 1915.

(4) I.M.S. – D.O. 145 = + 0′·6 Determined at Washington, November and December, 1915.

(5) D.O. 1911 – D.O. 145 = + 0′·7 Determined at Ottawa, April and November, 1915.

(6) D.O. 1911 – D.O. 145 = + 0′·85 From (3) and (4).

Not only may different instruments give rather large differences of declination, as the above results show, but it is evident that the difference between any two instruments is subject to quite a large variation. For example, from equations *A.* (1) and *A.* (2) the variation of I.M.S. – M.S. 15, is 1′; from *A.* (8), *A.* (9), *A.* (10) and *A.* (16) it is, for D.O. 1977 – D.O. 15, 2′; and the differences between the two standards, I.M.S. and Ag.S., range from – 1′·1 to – 2′·3.

In the case of horizontal intensity, there are large differences in the values obtained with different instruments as, for example, is shown by equations *B.* (1) and *B.* (2). These may be explained as due to errors in the determination of the constants for the instrument. But from a comparison of the equations the differences between any two seem to remain fairly constant.

The differences between comparisons of inclination also show some variation. I.M.S. – M.S. 89 shows a variation of ′·95, see *C.* (1) and *C.* (2). The value of D.O. 1911 – D.O. 145, determined at Ottawa and Washington, is in good agreement. In 1914, however, D.O. 1911 – D.O. 145 was 0′·0, showing that this value is by no means constant.

To account for these changes is, in most cases, difficult, if not impossible. However, this inconsistancy of instruments seems due to some change in the instruments rather than to errors of observation.

Below are given the results of the observations taken during the season of 1915, also a table showing the annual change at a few places.

The results for declination and horizontal intensity are all reduced to the Agincourt standard as has been done in previous years. The correction applied for the 1915 observations is 3′·6, and for horizontal intensity – ·00258*H*.

The inclination observations are reduced to our earth inductor No. 1911, and the correction applied for 1915 is 0′·7.

Station	Latitude	Longitude	Date	Declination	Range of Decl.	Dip	Hor. Int.	Total Int.
							C.G.S.	C.G.S.
Ottawa	45 23·6	75 43·0	Apr. 7–21	13 23·9W.	12·3	75 41·7	·14970	·60584
a Agincourt	43 47·0	79 16·0	"	6 28·1W.		74 43·0	·16042	·60859
Medicine Hat	50 03·0	110 40·4	May 12–13	21 58·4 E.	13·2	75 30·3	·15481	·61851
Dunmore	49 58·5	110 35·6	" 14–17–18	21 55·7 E.	14·3	75 24·4	·15528	·61603
Seven Persons	49 52·8	110 54·4	" 18–20	23 04·0 E.	12·5	75 03·9	·15937	·61838
Bow Island	49 52·4	111 23·4	" 21–22	23 12·7 E.	14·0	74 54·8	·15954	·61296
Taber	49 47·6	112 08·6	" 24–25	22 59·0 E.	17·0	74 42·8	·16184	·61385
Lethbridge	49 41·6	112 47·2	" 26–27	23 12·4 E.	12·0	74 29·9	·16299	·60984
Macleod	49 43·1	113 24·9	" 29–31	23 40·8 E.	15·8	74 31·1	·16304	·61080
Pincher	49 31·7	113 56·6	June 1– 2	25 09·2 E.	13·2	74 26·3	·16391	·61098
Frank	49 36·4	114 23·2	" 3– 4	24 14·2 E.	11·4	74 02·7	·16605	·60020
Michel	49 41·8	114 49·5	" 7– 8	24 14·2 E.	11·7	73 57·3	·16768	·60669
Fernie	49 30·2	115 04·0	" 9–10	24 12·0 E.	10·2	73 47·5	·16928	·60645
Jaffray	49 21·8	115 18·5	" 11–12–14	24 21·7 E.	15·3	73 33·2	·17153	·60591
Cranbrook	49 31·0	115 47·2	" 15–16–18	24 30·6 E.	14·0	73 33·8	·17125	·60343
Moyie	49 37·6	115 50·3	" 21–22	24 16·8 E.	17·5	73 23·7	·17223	·60268
Yahk	49 05·4	116 04·8	" 24–25	24 07·7 E.	16·0	73 11·6	·17394	·60175
Creston	49 05·7	116 30·6	" 26–28	24 03·8 E.	20·0	73 07·7	·17418	·60015
Proctor	49 37·0	116 57·0	" 30	24 31·6 E.	13·6	73 21·5	·17211	·60097
			July 1					
Lardo	50 08·5	116 56·8	" 2– 3	25 10·2 E.	12·5	73 48·2	·16803	·60240
Kaslo	49 54·5	116 55·0	" 7– 8	24 44·3 E.	15·8	73 36·9	·17003	·60275
Nelson	49 29·7	117 16·7	" 10–12	24 31·7 E.	16·2	72 54·7	·17648	·60059
b Ross'land	49 04·6	117 47·1	" 13–14	22 13·2 E.	14·6	74 36·5	·17682	·62852
Castlegar	49 19·3	117 39·0	" 16–17	24 46·2 E.	15·3	73 56·4	·17493	·63233
Paulson	49 12·0	118 07·2	" 19–21	24 33·2 E.	10·3	72 46·7	·17619	·59510
Grand Forks	49 01·5	118 25·2	" 21–22	24 32·9 E.	13·8	72 40·9	·17729	·59557
Midway	49 00·0	118 47·0	" 24–26	24 24·9 E.	13·6	72 18·6	·18064	·59447
Carmi	49 29·6	119 07·3	" 27–28	24 29·3 E.	15·0	72 52·8	·17451	·59282
Penticton	49 29·3	119 35·9	" 29–30	25 32·0 E.	16·6	72 37·6	·17862	·59820
Peachland	49 46·7	119 42·9	" 31	24 52·1 E.	13·4	73 13·9	·17163	·59490
			Aug. 1– 2					
Kelowna	49 53·5	119 28·5	" 3– 4	25 07·3 E.	9·0	73 09·5	·17191	·59335
Okanagan Landing	50 13·9	119 21·0	" 6– 7	25 21·4 E.	17·3	73 07·4	·17324	·59674
Enderby	50 33·0	119 08·4	" 9–10	25 55·8 E.	17·5	73 33·7	·16956	·59929
c Sicamous (Station "A")	50 50·3	119 01·2	" 12–13	25 59·2 E.	10·1	73 48·5	·16748	·60061
Sicamous (Station "B")	50 50·3	119 01·2	" 11–13	25 54·2 E.	11·7	73 51·2	·16689	·60017
Kamloops	50 40·8	120 20·7	" 16–17	25 53·0 E.	15·3	73 13·8	·17140	·59404
Vancouver	49 17·8	123 07·0	" 19–20	25 38·4 E.	12·0	71 33·0	·18732	·59230
Prince Rupert	54 18·2	130 20·1	" 23–24	29 01·7 E.	13·0	73 38·1	·16446	·58370
Hayspport	54 10·3	130 00·7	" 26–27	29 07·8 E.	13·9	73 34·6	·16486	·58327
Salvus	54 18·9	129 20·2	" 28–30	29 11·3 E.	14·8	73 34·1	·16584	·58027
Terrace	54 31·1	128 35·8	" 31	30 04·2 E.	15·6	74 02·6	·16241	·59077
			Sept. 1					
Pacific	54 45·8	128 33·0	" 3– 4	30 17·1 E.	11·0	74 25·6	·15865	·59095
Kitwanga	55 05·9	128 03·3	" 7– 8	30 21·5 E.	12·4	74 45·7	·15563	·59212
New Hazelton	55 14·6	127 34·5	" 10–11	30 11·8 E.	16·5	75 01·4	·15255	·59030
Smithers	54 46·7	127 11·8	" 13–16	29 36·3 E.	14·2	74 59·4	·15367	·59335
Houston	54 24·1	126 39·9	" 17–18	29 05·9 E.	10·4	74 43·3	·15610	·59239
Burns Lake	54 13·6	125 46·6	" 19–20	29 47·6 E.	8·8	74 25·6	·15901	·59240
Endako	54 04·9	125 02·2	" 21	29 05·0 E.	6·3	74 55·7	·15460	·59455
Vanderhoof	54 01·2	124 02·2	" 24–25	28 52·4 E.	10·4	75 17·5	·15170	·59748
Fort George	53 54·6	122 44·9	" 29–30	28 47·4 E.	10·2	75 10·3	·15308	·59815
Winnipeg	49 51·9	97 10·0	Oct. 4– 5	13 40·4 E.	13·3	78 12·3	·12040	·63304
a Agincourt	43 47 0	79 16·0	Nov.	6 30·5W.		74 44·7	·15997	·60798
Ottawa	45 23·6	75 43·0	" 2–10	13 26·2W.	11·2	75 42·3	·14031	·60470

NOTE—*a*—The values for Agincourt were taken from the JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA.

b—Strong local attraction exists.

c—Station "A" is approximately a re-location of the D.O. station of 1908. Station "B" is about 600 feet north of station "A", which is not likely to be suitable for re occupation.

ANNUAL CHANGE

Station	Date	*Obs.	Declination	Dip	Hor. Int.	Date	*Obs.	Declination	Dip	Hor. Int.	Aver. Annual Change Dec.	Dip	Hor. Int
			° ′	° ′	C.G.S.			° ′	° ′	C.G.S.	′	′	C.G.S.
Ottawa	Oct. 1906	C.I	12 44·4 W.	75 39·1	·15222	Nov. 1915	D.O.	13 26·2 W.	75 42·3	·14031	- 4·6	0·3	- ·00032
a Agincourt	Sept. 1906	M.S.	5 47·3 W.	74 35·9	·10388	Sept. 1915	M.S	6 29·2 W.	74 43·9	·16017	- 4·7	0·9	- ·00041
b Medicine Hat	June 1911	D.O.	21 58·3 E	75 30·6	·15463	May 1915	D.O	21 58·4 E.	75 30·3	·15481	0·0	0·0	- ·00004
c Macleod	Oct. 1908	C.I.	23 31·5 E.	74 37·7	·16344	May 1915	D.O.	23 40·8 E.	74 31·1	·16304	1·4	- 1·0	- ·00006
Sicamous	Aug. 1908	D.O.	25 52·8 E.	73 53·6	·16756	Aug. 1915	D.O.	25 59·2 E.	73 48·5	·16748	0·9	- 0·7	- ·00001
Vancouver	Aug. 1908	D.O.	25 23·3 E.	71 43·0	·18763	Aug. 1915	D.O	25 38·4 E	71 33·4	·18732	2·2	- 1·3	- ·00004
Fort George	Sept. 1913	D.O.	28 46·9 E.	75 10·4	·15354	Sept. 1915	D.O.	28 47·4 E.	75 10·3	·15308	0·2	0·0	- ·00023
Winnipeg	Sept. 1906	C.I.	13 59·0 E.	78 07·4	·13163	Oct. 1915	D.O.	13 40·4 E.	78 12·3	·12940	- 1·9	0·5	- ·00025

NOTE—*C. I.—Carnegie Institution; M. S.—Meteorological Service; D. O.—Dominion Observatory.

a Values taken from the JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA.

b The stations of 1911 and 1915 are separated by about one-fourth of a mile.

c Values taken from "Researches of the Department of Terrestrial Magnetism."

A "+" sign under "Average Annual Change" of Declination indicates that eastern declination is increasing and western declination decreasing, while a "−" sign means the reverse.

MEETINGS OF THE SOCIETY

At Toronto

April 18, 1916.—A regular meeting was held in the rooms, 198 College St., at 8 p.m. The President, Dr. A. D. Watson, in the chair.

Announcement was made by the chairman of a special lecture by Professor Percival Lowell, to be given in the auditorium of the Technical School on the 27th of April.

Mr. A. F. Miller was then called on for his paper on "Precession." In it he explained what is meant by the "Equinox" and told of some of the probable methods used by the ancients for fixing the equinoctial points. Determination of the length of the year led Hipparchus to discover precession. Newton explained the cause of the precession and showed the effect on the earth's axis. The effect of lunar attraction was also explained. Constant revision of star places is necessary to take account of precession and nutation. The precessional period lasts for 25,000 years, after which our polar axis will then point to the same part of the heavens again.

The lecturer also explained how in about 13,000 years the sun will change from where it is now in summer to where it is now in winter or what are now called summer constellations will then be winter ones.

Some astronomical and physical changes were given as being not due to precession, chief of which were stated as the climate on the earth.

May 2nd.—A regular meeting was held in the rooms at 198 College St., at 8 p.m. Mr. A. F. Miller, 1st Vice-President, in the chair.

Several members referred to the beautiful aurora visible the night of April 28th.

Professor A. T. DeLury was then called on for his address on "The Principle of Relativity." He explained why certain philosophers considered it was necessary to reconstruct the foundation of our mathematical science, chiefly on account of paradoxes that had arisen in physical science in the study of light. Illustrations were given of what relative motion meant and how impossible it was to disassociate the idea of relativity from any motion in space. Nothing is at rest.

Several axioms of the relativists were read and explained, and the lecturer concluded his address by the remark that the new theory does not, however, destroy the usefulness or accuracy of our former conceptions in regard to forces and velocities which are for us experimentally possible.

Dr. Chant moved that the thanks of the R.A.S.C. be tendered to the Board of Education, the Principal of the Technical School and the attendants for the use of the Auditorium on the occasion of the lecture by Professor Lowell, on the evening of April 28th. Carried.

Moved by Mr. F. Hooker, seconded by Mr. A. F. Hunter, that the President and Corresponding Secretary be and are instructed to frame and forward an expression of the sympathy of the Society to the widow and family of our late lamented Honorary President, Dr. King. Carried.

Moved by the President, that the Corresponding Secretary forward an expression of sympathy to Dr. Marsh, one of our Council, on the occasion of the death of his wife. Carried.

May 16.—The regular meeting of the Society was held in the rooms at 198 College St., at 8 p.m. Dr. Watson, President, in the chair.

Communications were reported by the Secretary as having

been received from Mrs. King, and also Dr. Marsh, thanking the Council and members of the Society for their sympathy.

The following were elected members of the Society:—

J. W. Darrach, 93 Dupont Street, Toronto.

H. J. C. Ireton, R.R. No. 2, Perth, Ont.

Mr. Collins referred to the predictions for the next two weeks as given in the HANDBOOK.

Mr, A. F. Miller read a translation which he had made of Daudet's "Shepherd's Story of the Stars."

A discussion on the saving of daylight was participated in by several members.

Dr. Watson read his monologue on "Galileo" and his poem on "The Wonder Star."

W. E. W. JACKSON, *Rec.-Sec.*

AT OTTAWA

January 28, 1916.—The second meeting of the spring term of the Society was held in the Carnegie Library, at 8 p.m..

Mr. W. E. Harper's lecture on "Nebulæ" was much appreciated by the goodly number of members and friends of the Society who were present. A large number of very fine slides, which had been made from some negatives taken at Mount Wilson, were exhibited. Type nebulæ were shown and commented on. An interesting question was raised as to whether nebulæ have a life history of their own and whether or not the "holes" in star groups are not caused by the "dead nebulæ," blotting out the stars. Several slides were shown of nebulæ in the centre of holes, at the end of lanes in holes, and with the stars on one side more numerous than on the other.

February 11.—The third meeting of the spring term was held in the Geodetic Survey Building, at 3 p.m. The lecturers for the meeting were R. M. Stewart and F. A. McDiarmid. The former spoke on "The New List of Longitude Stars," and the latter on the "Methods Used in Correcting Gravity Measurements for Topographical Influences."

In speaking on the "New List of Longitude Stars," Mr. Stewart showed the various things which had to be considered in selecting stars for the list and gave examples of the methods used in correcting the observations and reducing the values of the position of the stars. Systematic errors were to be carefully watched for and removed from the results. The work involved in preparing such a corrected list is very great, Mr. Stewart said that there were calculations completed once and almost completed a second time, as a check. Dr. Klotz and Dr. Plaskett both complimented the lecturer on the value and precision of the work done.

Mr. McDiarmid gave a description of the different methods used in compensating the gravity measures for topography. The method outlined by Hayford and Bowie was dealt with more fully, the equations involved being worked out and the application of the method shown.

Dr. Klotz, who occupied the chair, in closing the meeting spoke of the application to seismology of the same ideas of isostatic compensation as was involved in the correction of gravity measured by Hayford and Bowie's method. He showed how the relationship between the computed depth of the magma layer pointed exactly to 228 km. per minute as the velocity of the *L* or surface waves if one took the average period of such waves as 20 sec. From actual experience the average value of the velocity for over two hundred quakes was found to be 228 km. per minute.

February 25.—The fourth meeting of the spring term was held in the Carnegie Building, at 8 p.m. Mr. J. D. Craig lectured on the subject, "How a Surveyor Lives, Moves and has his Being." In spite of a very bad storm the attendance was fairly good and the lecture was very much enjoyed by all who had ventured out.

Mr. Craig had a large number of slides and showed by them and by his lecture various phases of surveying in the north country between Alaska and Canada. Stories were told of the

life lived by a surveyor and his men—the difficulties of crossing glaciers, going up streams, carrying provisions inland, etc., were very interesting. The line first laid out as boundary some years ago was shown in a photograph with the newly surveyed line and the slight difference showed clearly the care taken in the first survey when instruments were not nearly so precise as now.

March 10.—The fifth meeting of the spring term was held in the Geodetic Survey Building at 3 p.m. Mr. French gave a paper on "Magnetism."

The instruments used were described and were demonstrated as they stood on the table. A short history of magnetic surveys was given and then the work as taken up by Mr. French was gone into in more detail. The life of a surveyor engaged in this work is one which takes him over a great deal of country. In the magnetic survey of Canada the stations so far have been taken along railway lines as far as possible.

March 22.—The sixth meeting of the spring term was held in the Carnegie Library, at 8 p.m. The lecturer of the evening was Professor S. A. Mitchell, Director of the Leander McCormick Observatory, University of Virginia.

Professor Mitchell is not only a man who is fully qualified to speak on the subject of stellar distances because of his knowledge of the subject but he proved himself a very pleasant speaker as well. The slides were numerous, well chosen and clear, and Dr. Mitchell succeeded in making his subject clear to all present, astronomers and laymen alike. The three methods first used for determining the distances of the stars were described in detail—the heliometer, the zenith telescope and the micrometer eyepiece. These were used by Bessel, Henderson and Struve, respectively. The modern method by photography was next discussed and its advantages shown.

Here and there in the course of his lecture Dr. Mitchell gave short descriptions of places he had visited. In connection with

a picture of Gibraltar he pointed out that the particular face of the cliff which we are usually familiar with through the advertisements of a certain insurance company does not face the sea, as the pictures show, but the land of Spain.

The lecturer was tendered the thanks of the meeting, several members voicing their appreciation of the lecture.

March 31.—The seventh meeting of the spring term was held in the Geodetic Survey Building at 3 p.m. The President was in the chair. Mr. F. B. Reid gave a lecture on "Precise Levelling." The paper had special reference to the precise levelling required by the Government of Canada.

Mr. Reid pointed out that the work necessitated extreme precautions to prevent error. The levelling is carried along the railroad tracks. This has the advantages of good turning points for the rods, easy travel and good positions for bench marks, but has the disadvantage of the great radiation from the tracks which tends to affect the levels. Maps were shown giving the course of the levels. It was interesting to note that where two lines of levels started from the same point and proceeding by different routes again met the heights as determined along the two routes agreed within a fraction of a foot in every case. The levelling has been carried to tide water at Halifax and west to beyond Banff. It has also been carried from tide water at Vancouver to within about 275 miles of the other line of levels. It is hoped that this gap will be closed this summer.

The material presented was very interesting indeed and one could not fail to be impressed with the idea, that though the results were interesting and highly satisfactory in point of agreement, that the labor of so carrying out the work as to insure such precise results must have been extremely tedious.

April 7.—The eighth meeting of the spring term was held in the Geodetic Survey Building. Dr. J. S. Plaskett gave a paper on "The New 72-Inch Telescope," which will be erected at Victoria. The lecture was illustrated by slides made from

photographs taken of the telescope in the course of erection. After a short description of the chief differences in the two types of telescopes, Dr. Plaskett said that the reflector had three advantages which the refracting telescope could never hope to overcome,—lower cost for the same light-gathering power, much smaller absorption of light, and the possibility of making telescopes of larger light gathering power, since, after a refracting telescope has an object glass greater than about 40 inches, the increase in the diameter of the glass is offset by the greater absorption of light by its necessarily increased thickness.

The description of the new telescope was divided into two parts,— the optical parts, and the mounting. The mirror weighs over 3 tons. It was cast in Belgium, and was shipped out three days before war broke out. It has been worked up by Brashear, of Pittsburgh. The quality is very good. The mirror is 73 inches in diameter, 13½ inches thick and has a hole in the centre 6 inches in diameter. The figuring makes it $^{9}/_{10}$ inch thicke at the edge than in the centre. It was first ground with crushed steel to approximate dimensions, then with finer and finer grades of water-washed emery and then polished. It is now in the process of being "figured" or made to have a surface which is a true paraboloid of revolution. This figuring is done by the cut and try method, tested by interferometer tests and must be true to within 1/200,000 part of an inch. The light gathering power of this mirror is about 100,000 times that of the human eye, or about 23 times that of the large telescope here at Ottawa. It has an equivalent focal length of 108 feet when used with the Cassegrain mounting.

The mounting is that of an equatorial telescope. The telescope itself weighs from 14 to 15 tons. There are three rates of motion. The fast motion is equivalent to one revolution in 8 minutes. The second is equivalent to one revoluion in 36 hours, and the slow motion would give one revolution in 30 days. The ball bearings which support the telescope at the axis are specially constructed to take up any irregularity in the direction of the two bearings. The balls are 2½ inches in diameter. The

mounting weighs about 60 tons, 45 tons being moveable parts and 15 tons stationary. The worm wheel for driving the telescope weighs from 4000 to 5000 lbs. and may be turned readily on its axis by the finger.

The dome housing the telescope will be 66 feet in diameter with a clear opening of 15 feet, which can be protected by wind shields. Some of the improvements in the new telescope are the bearings which assume the weight of the telescope without special compensating arrangements, the specially strung skeleton portion of the telescope, the ability to change from one to the other of the three arrangements of principal focus, Newtonian mirror or Cassegrain mirror, by moving a mass of only about 300 lbs., instead of a whole section of tube, and the dome arrangements which are to be most complete and convenient.

April 14.— The ninth meeting of the spring term was held in the Carnegie Library, at 8 p.m. The President was in the chair. The lecturer of the evening was Dr. W. H. Collins, of the Geological Survey, and his subject was "The Age of the Earth."

Dr. Collins referred throughout his lecture to "The Great Stone Book" or those built-up layers of rock which lie above the unchanged fire-formed rock. This book is sixty miles thick and divided into a large number of chapters, as the layers might be called. The fossils and remains in each layer tell their story of the times in which the layer was laid down. Only in the last section of the book do we find any record of man. Slides showing the remains and the built-up features of these men and near-men were shown. After tracing backward the various changes in the life shown by the fossils, there was found a period of unknown length in which the change from unicellular to multicellular animals occurred. Behind this again were other periods of unknown length but these unknown periods were probably of great length, since the law of habit requires a long period of time for the formation of a habit which shall last a long time and the habit of cell change persists to this day.

Finally, Dr. Collins showed the different methods used to arrive at a probable value of the age of the earth. The sediment deposited every year forms a means of determining how many years it took to deposit the sediments which exist. Estimates based on this method vary from Ussher's value of 6000 years to 250 million years. Another method is that of the time required at a given rate to produce the saltiness now present in the ocean. A third method is one based on a study of radioactivity. Radium breaks down into helium and from a study of the proportion of helium present in radium-bearing rocks it has been estimated that 400 million years would be the order of time necessary for this. It seems to be possible only to set upper and lower limits to the value of the age of the earth. The lower limit is probably about 40 million years and the upper limit 400 million years.

E. A. Hodgson, *Sec.*

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

April, 1916

Temperature.—The mean temperature did not deviate very much from the normal in any part of the Dominion. Positive departutes ranging between 1° and 3° prevailed over a larger territory than did the negative, and included Alberta and Western Saskatchewan, most of Ontario and Quebec and New Brunswick. The negative departures, which were generally less than 2°, occurred in parts of British Columbia, in Eastern Saskatchewan and Manitoba, and in Nova Scotia and Prince Edward Island.

Precipitation.—Precipitation was considerably in excess of the average over Western and Southern Ontario, while elsewhere in the Dominion the departures were relatively small. In Manitoba the departures were very generally negative, while over the remainder of the West and in British Columbia, they were positive. From the Ottawa Valley east, the departures were negative, excepting only some parts of Eastern Nova Scotia and the Island.

May, 1916

Temperature.—The temperature was nowhere above the average over the Dominion, except in the Gaspé Peninsula where there was a positive departure of about 2°. On the other hand

the temperature was nowhere much below the average, the largest negative departures, amounting to about 3°, occurring in British Columbia, Alberta and Saskatchewan.

Precipitation.—The precipitation throughout British Columbia was below the average, also in the Maritime Provinces, south of the Miramichi River, elsewhere over the large remaining portion of the Continent it was above the average, and in nearly all localities to a very marked extent. The chief negative departures were 2 inches at Vancouver and 2·1 inches at St. John; and the chief positive departures were in the Western Provinces, 2·90 inches at Prince Albert; 1·80 inches at Medicine Hat; 1·10 inches at Battleford, and 1·0 inch at Swift Current. In Ontario, 2·60 inches at Parry Sound; 3·80 inches at Elora and Paris; 2·70 inches at Toronto; 3·40 inches at Kingston, and 4·40 inches at Ottawa. In Quebec, 3·20 inches at Montreal; 3·50 inches at Quebec and 2·10 inches at Brome.

Temperature for April and May, 1916

Station	April		May	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	68	8	80	30
British Columbia				
Atlin	59	12	72	22
Agassiz	69	34	76	30
Barkerville	59	12	67	23
Kamloops	74	28	81	35
New Westminster	65	34	76	34
Prince Rupert	63	8	74	30
Vancouver	62	34	73	36
Victoria	63	37	68	36
Western Provinces				
Battleford	76	15	77	21
Calgary	76	22	74	23
Edmonton	70	17	75	27
Medicine Hat	85	16	93	27
Minnedosa	64	2	76	20
Moose Jaw	77	11	80	19
Oakbank	62	- 6	73	23
Portage la Prairie	67	4	78	28
Prince Albert	74	2	78	20
Qu'Appelle	68	0	76	22
Regina	72	20	77	20
Saskatoon	74	14	75	18
Souris	64	3	79	23
Swift Current	75	2	76	22
Winnipeg	66	3	75	23
Ontario				
Agincourt	71	24	81	33
Aurora	70	21	76	32
Bancroft	71	16	79	29
Barrie	70	20		
Beatrice	65	15	74	29
Berlin	71	22	77	33
Bloomfield	67	25	73	35
Brantford				
Chapleau	65	4	72	8
Chatham	76	24	83	34
Clinton	67	18	77	30
Collingwood	72	20	73	30
Cottam	73	25	80	33
Georgetown	71	24	77	35
Goderich	69	21		
Gravenhurst	69	15		
Grimsby	74	28	80	36
Guelph	72	22	77	33
Haliburton	72	14	82	26
Huntsville	69	13	77	28
Kenora	64	0	71	10
Kinmount	69	15	76	26
Kingston	64	20	70	36
London	73	21	82	31
Lucknow	68	11	74	27
Markdale	70	14	79	30
North Gower	75	20	79	30
Oshawa	66	24	78	31
Ottawa	71	20	80	33
Paris	74	25	82	28
Parry Sound	66	12	78	30
Peterboro'	71	25	77	29
Port Arthur	64	14	75	27
Port Burwell				
Port Dover	68	24	80	35
Port Stanley	67	22	78	37
Queensborough	72	21	79	33
Ronville	70	12	75	28
Southampton	69	21	70	31
Sundridge				
Stonecliffe	72	14	83	27
Stony Creek	75	28	81	37
Toronto	69	25	81	37
Uxbridge	70	21	75	33
Wallaceburg	75	25	75	32
Welland	72	25	80	35
White River	62	-10	71	20
Quebec				
Brome	70	16	80	25
Father Point	52	12	70	28
Montreal	66	24	80	34
Quebec	63	18	79	31
Sherbrooke	67	19	80	27
Maritime Provinces				
Charlottetown	52	20	64	32
Chatham	58	20	76	32
Dalhousie	56	15	65	32
Fredericton	66	18	76	30
Halifax	62	24	72	30
Moncton	57	18	73	27
St. John	59	24	84	40
Sussex	60	21	75	29
Syndey	54	16	68	30
Yarmouth	59	24	62	32

MAGNETIC OBSERVATIONS

March, 1916

The Magnetic Curves obtained at Agincourt during the month of March indicate that disturbing forces were in operation throughout the greater part of the month. Only six days were classified as quiet, *viz.*, 13, 15, 16, 23, 27, 28. The more pronounced storms occurred on the 3rd, 8th, 9th, 17th and from the 28th to the 31st. On the 3rd the departures from the normal were small, but the disturbance was quite active throughout the 24 hours.

On the 8th, from 8 hours until noon, a large bay was recorded on each trace, the westerly declination having maximum increase of 45′, horizontal force a decrease of 229γ and vertical force a decrease of 62γ. A second disturbance on the 8th began about 20 hours and continued to 21 hours on the 9th. This storm showed very rapid oscillations in the disturbing forces. In D the movements were rapid but of small amplitude, whilst in both H and Z more activity was shown, particularly about midnight of the 8th, when amplitudes of the vibrations ranged from 140γ to 210γ in H, and from 30γ to 88γ in Z, and again from 16 to 18 hours of the 9th, when the ranges in H were from 90γ to 150γ.

The disturbances of the 17th began about 19 hours of the 16th with gradual decrease of westerly declination of horizontal force and of vertical force up to 1 hour of the 17th when the H and Z decrease became very rapid during the next 22 minutes, H passing below the limit of the paper and Z reaching about 200γ below normal, at the same time D increased 1° 25′ and all three returned to normal between 2 hours and 3 hours followed by small rapid fluctuations for a couple of hours.

The longest disturbed period was, however, from the 28th to the 31st and in this the most active part was from 18 hours to 23 hours of the 29th. In D the departures from normal were only pronounced during this most active part when the amplitudes of the swing reached 1°. In H and Z a pronounced bay

occurred with minimum of force about 9 hours 40 minutes of the 29th and return to normal about noon. During the most active period the amplitude of the oscillations in H ranged from 110γ to 200γ and reached a maximum of 185γ above normal, and at the same time Z reached a maximum of about 200γ above normal. Another large negative departure of 165γ was recorded in H from 2 hours to 4 hours of the 31st and of 115γ in Z.

Auroræ were recorded quite generally over Canada during the first 12 days of the month, again on the 16th and 17th, the 25th and from the 28th to the 31st, that of the 29th being particularly well observed from places in Ontario and Quebec.

April, 1916

The magnetic forcess, as registered at Agincourt, during the month of April, displayed considerable activity, and this was most pronounced in a storm beginning about midnight of the 24th, and continuing to the end of the month. This disturbance was notable for the large range in both direction and force and also for the rapidity of the oscillations which were particularly large during the afternoon and evening of the 25th and during the night of the 27th and 28th.

Auroræ were recorded fairly generally throughout Canada from the 22nd to the 29th and locally in the Western Provinces from 1st to 9th.

Numerous small spots were apparent on the sun's surface throughout the month.

March, 1916		D. West	H	Z	I
		° ′			° ′
	Mean of Month	6 33·1	0·15988	0·58572	74 43·9
	Maximum	7 36·2	0·16173	0·58570	
	Date of Maximum	17	29	29	
	Minimum	5 54·8	*0·15567	0·58374	
	Date of Minimum	8	17	17	
	Monthly Range	1 41·4	0·00606	0·00396	
Mean Daily Amplitude	From hourly readings	0 10·4	0·00046	0·00025	
	From means of extremes	0 24·2	0·00120	0·00064	

H and Z are expressed in C.G.S. units.

* Minimum of H estimated as light passed beyond limit of photographic paper and remained off from 1 hour 20 minutes to 2 hours 10 minutes of the 17th.

April, 1916		D. West	H	Z	I
		° ′			° ′
	Mean of Month	6 32·9	0·15995	0·58559	74 43·4
	Maximum	7 13·6	0·16331	0·58785	
	Date	29	25	29	
	Minimum	5 57·6	0·15553	0·58335	
	Date	28	29	28	
	Monthly Range	1 16·0	0·00778	0·00450	
Mean Daily Amplitude	From hourly readings	0 13·2	0·00015	0·00023	
	From means of extremes	0 25·9	0·00112	0·00060	

H and Z are expressed in C.G.S. units, (1 γ = 0·00001 C.G.S.

All results are reduced to International Magnetic Standard.

W. E. W. J.

Earthquake Records by the Milne Seismograph

TORONTO

Sir Frederick Stupart, Director.

P.T. = Preliminary Tremors, L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1916	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
1567	Mar. 1			19 52·5	19 55·2	20 03·4	0·2	
1568	" 4			8 12·4) 8 15·4)	8 25·9	8 50·5	0·3	
1569	" 12		7 44·5	7 45·7) 7 50·3)	7 53·4	8 6·0	0·3	
1570	" 16			23 0·7	23 3·0	23 9·6	0·3	
1571	" 18			1 50·3?		1 56·4	0·1	
1572	" 19			13 8·8) 13 14·3)	13 16·3	13 26·3	0·2	
	" 26	Quake	possibly	lost owing to	stopping of	clock		
1573	" 28			7 56·2		8 12·0	0·2	
1574	" 29		19 9·1	19 11·6	19 15·5	19 31·9	0·2	
1575	" 31			11 28·7	11 31·4	11 58·6	0·9	
1576	" 31			16 35·7		16 36·7	0·05	
1577	" 31			16 55·2		16 58·2	0·1	
1578	Apr. 2			8 40·7	8 41·0	8 47·4	0·6	
1579	" 7	9 45·6	9 59·6	10 13·5	10 51·8) 11 34·9)	12 46·8	1·3	Reinforce at 11h 22m·1.
1580	" 7			15 56·9		15 59·8	0·05	
1581	" 11			3 56·8		3 58·9	0·2	
	" 14	At 20h	50m earthq	uake missed,	visitors in	the room.		
1582	" 14			22 6·0) 22 42·8)		22 43·9	0·2	
1583	" 15	13 11·2		13 51·3	14 5·6	14 50·3	0·5	
1584	" 16			22 52·8) 22 54 3)		0 13·8?	0·2	
1585	" 18	4 11·4	4 19·2	4 29·8	4 40·7	7 02·0	1·4	
1586	" 21	11 49·8	11 57·0) 12 03·1)	12 14·2	12 20·6	13 52·4	1·5	
1587	" 24	4 32·3	4 36·9	4 38·1	4 38·4	5 54·0	1·8	2,908 km
1588	" 24	8 9·9	8 15·4	8 17·4 8 21·0	8 23·0	11 22·0	11·0	
1589	" 26		2 33·2	2 35·6	2 41·2	4 43·0	11·0	
1590	" 26			6 39·8 6 43·1	6 46·2		0·8	
1591	" 26			7 30·4 7 33·3	7 39·5	8 28·5	0·8	
1592	May 3			5 42·2		6 0·6	0·2	
1593								
1594	" 9			15 53·4		16 21·4	0·05	
1595	" 10	21 44·5?	21 49·6	21 53·7	22 0·8	22 48·0	3·4	
1596	" 11			10 21·6 10 21·9	10 22·4	10 52·4	1·6	
1597	" 14			0 32·0 0 39·8		0 46·0	0·05	
1598	" 17			13 22·4 13 27·7		13 41·2	0·1	
1599	" 26			21 13·5		21 18·5	0·2	

Period of boom 18 seconds. Pillar inclinations 1 mm. = 0″·50.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1916	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
1571	Mar. 4	7 39·4	7 48·9	7 54·4	7 57·9	8 27·6	1·0	3,210 km.
1572	" 12	7 48·5	7 51·0	7 54·4	7 59·9	8 10·9	0·4	?1,420 km.
1573	" 16	22 40·1	22 41·1	22 42·6	22 44·6	22 51·5	1·5	500 km.
1574	" 19		12 49·1?	12 52·1?	13 00·5	13 19·8	0·2	
1575	" 28	7 36·4	7 37·3	7 38·4	7 39·2	7 48·9	0·5	150 km.
1576	" 29	19 21·0	19 23·0	19 24·3	19 24·5	19 28·0	0·2	
1577	" 31	11 11·4	11 12·1	11 12·9	11 13·4	11 26·3	4·5	100 km. Possibly off Vancouver Island.
1578	" 31	16 37·0	16 38·0	16 38·7	16 39·0	16 44·1	0·6	590 km.
1579	Apr. 2	8 22·9	8 23·4	8 23·9	8 24·7	8 31·9	1·2	830 km.
1580	" 6	19 03·9	19 04·2	19 04·2	19 04·5	19 06·9	0·2	?180 km.
1581	" 7	10 04·4		10 10·8	10 11·0		0·2	
1582	" 7	10 50·0	10 55·0	10 59·4	11 06·4	11 51·5	0·2	3190 km.
1583	" 7			16 12·1		16 19·6	0·05	
1584	" 11	3 39·5		3 41·0	3 41·5	3 45·5	0·6	830 km.
1585	" 14			20 52·6	20 54·1	21 02·1	0·2	
1586	" 14			21 54·1	21 55·1		0·1	
1587	" 15	13 33·5	13 39·6	13 47·1	13 51·1		0·2	4,220 km.
1588	" 15			14 38·1	14 40·6	15 33·1	0·3	
1589	" 16	22 45·2		22 47 2	22 48·2	23 00·2	0·4	
1590	" 18	4 07·6	4 08·6	4 12·0	4 16·9	5 54·3	1·5	520 km.
1591	" 21	11 43·0		11 52·0	11 52·0	13 07·3	1·1	
1592	" 24	4 42·6	4 44·6	4 46·6	4 48·6	5 34·6	0·4	1,120 km.
1593	" 24	8 10·9	8 19·8	8 31·6	8 40·9	9 59·6	1·5	
1594	" 26	2 32·6	2 41·5	2 45·9	2 59·7	3 45·4	1·2	7,425 km.
1595	" 26	6 56·5			7 04·9	7 13·9	0·3	
1596	" 26			7 49·8	7 53·3		0·2	
1597	May 3	5 23·1?	5 29·1?		5 35·5		0·1	?4,200 km.
1598	" 10	22 07·0	22 10·9	22 13·4	22 17·1	22 35·5	0·2	2,330 km.
1599	" 11	10 16·9?		10 18·5	10 20·5	10 27·1	0·6	?870 km.
1600	" 17			13 34·2?	13 35·7	13 38·2	0·1	
1601	" 26			2 19·8	2 21·8		0·1	

Boom period 18 seconds. Pillar inclination 1 mm. = 0″·54

VERTICAL COMPONENT

Date 1915	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
	h m s	h m s	h m s	h m s	h m s	μ	
Mar. 31	11 31 39	11 12 25	11 12 50	11 13 25	11 32 35	* 85	450 km.
" 31	16 37 45	16 38 20	16 38 45	16 39 00	16 52 00	* 17	320 km.
Apr. 2		8 24 10	8 24 10	8 24 35	8 42 52	* 15	640 km.
" 6		19 05 53	19 05 53	19 06 53	19 12 51	* 3	?1,120 km.
" 7	10 04 38	10 09 26	10 15 54			*	3,070 km.
" 18			4 12 06	4 18 31		* 7	
" 21		11 43 50	11 52 10	11 52 10		* 7	440 km.
May 11				10 20 03		* 3	

* True earth movement.

J. V.

Recently Elected

Honorary Fellows, Royal Astronomical Society of Canada

JOHN OSCAR BACKLUND, Ph.D., For. Assoc. R.A.S.,
Director of the Imperial Observatory, Pulkowa, Russia.

BENJAMIN BAILLAUD, For. Assoc. R.A.S.,
Director of the Paris Observatory, Paris, France.

FRANK WATSON DYSON, M.A., LL.D., F.R.S.,
Astronomer Royal, Royal Observatory, Greenwich, Eng.

PERCIVAL LOWELL, A.B., LL.D.,
Director of the Lowell Observatory, Flagstaff, Arizona.

FRANK SCHLESINGER, B.S., A.M., Ph.D.,
Director of the Allegheny Observatory; Professor of Astronomy, University of Pittsburgh, Pittsburgh, Pa.

HERBERT HALL TURNER, D.Sc., D.C.L., F.R.S.,
Savilian Professor of Astronomy, Oxford, England.

Official Ballots were sent out to all Members of the General Council of the Society, and by unanimous vote the above were elected as Honorary Fellows.

June 1, 1916.

A. D. WATSON, *President.* J. R. COLLINS, *General Secretary.*

ASTRONOMICAL NOTES

ADAMS SPECTROSCOPIC METHOD, MEASURING STELLAR DISTANCE.—A thing now being talked about by astronomers is a method proposed by Mr. Walter S. Adams, of the Mount Wilson Solar Observatory, for determining the distance of stars by a spectroscope. It is unnecessary to say what an immense advance it would be in astronomy if such a scheme is realised, and there is good evidence that it will be, though it may at first sound as unlikely as, no doubt, did the suggestion of finding star

velocities with a spectroscope when it was first proposed. The gist of Mr. Adams's method is as follows :— He derives the distance through, or by means of, the absolute luminosity. He says, " If two stars which have closely the same type of spectrum differ greatly in luminosity, it is probable that they also differ greatly in size, mass, and in the depth of the atmospheres surrounding them. Accordingly, we might hope to find in these stars certain variations in the intensity and character of such spectrum lines as are peculiarly sensitive to the physical conditions of the gases in which they find their origin, in spite of the close correspondence of the two spectra in general. If such variations exist and a relationship may be derived between the intensities of these lines and the intrinsic brightness of the stars in which they occur, we have available a means of determining the absolute magnitude of stars, and hence their distances."

The last sentence scarcely requires explanation ; but as the absolute magnitude of a star is defined as its apparent magnitude when supposed at unit distance, it is evident that its actual observed magnitude will, by comparison, show how many units the star is away. An essential of the method is to choose lines which are found specially weak in the spectra of some stars and strong in others, the stars being of the same spectral type. Two such lines are the calcium line at λ4455, and the strontium line at λ4216. The calcium line is very strong in the spectrum of 61^1 Cygni, and relatively weak in that of α Tauri. The strontium line is weak in the Cygnus star and strong in α Tauri. The parallaxes of these stars have been found by other methods, and hence their absolute magnitudes. The luminosity of α Tauri is over 1,100 times as great as that of 61^1 Cygni, and hence there is a guide to the behavior or the appearance of these two lines in the spectra of stars of different luminosity. Mr. Adams then evolved a system of accurate evaluation of the weakness or strength of the lines, and established a numerical relationship between the intensities of the lines and the absolute magnitudes of the star in which they occur. He then applied this method

to many stars whose parallax had been already determined, for which there were spectrum observations, and the agreement of the new "spectroscopic" parallaxes with those already found for the same stars is excellent. The measured parallaxes in the list range from 0″·05 to 0″·40, and the average deviation of the new values is 0″·024. The star δ Eridani shows a large discordance, the spectroscope giving 0″·05, whilst the parallax, as found at Yale, was 0″·19; but in most cases the accordance is striking. The publication in which this is to be found, as well as some other papers on the subject of spectroscopy, is the "Proceedings of the National Academy of Sciences," (Washington, D.C.) for March last. — H. P. Hollis, in *English Mechanic and World of Science*, No 2674.

Comet 1916*a* (Neujmin). — A possible connection between this comet and Encke's comet has been traced by H. Svoboda. A comparison of their orbit elements indicates that Neujmin's comet originated in the path of Encke's comet, possibly by a partition of the latter. — *Nature*, No. 2434.

Relative Velocities within Planetary Nebulæ. — Since our announcement of the discovery of spectroscopic evidence of the rotation of the planetary nebula N.G.C. 7009 (R.A. = $20^h\ 58^m$), we have extended the observations to a number of well-known planetaries. We have obtained spectrograms, with high dispersion for this line of investigation, of the following objects:

		h m	° ′
N. G. C.	418	= 5 22·9	= - 12 46
N. G. C.	2392	7 23·3	+ 21 7
N. G. C.	3568	12 30·4	+ 83 7
N. G. C.	6210	16 40·3	+ 23 59
N. G. C.	6543	17 58·6	+ 66 38
N. G. C.	6572	18 7·2	+ 6 50
N. G. C.	7009	20 58·7	- 11 46
N. G. C.	7027	21 3·3	+ 41 50

Our spectrograms of N. G. C. 418 and N. G. C. 3568 show no inclination of the nebular lines, while those of all the other objects give marked evidence of relative motion within them. With the exception of N. G. C. 2392 the results for the rela-

tive motions within each nebula appear to be capable of interpretation on the hypothesis that the nebula is rotating, although there are indications, at least for the outer portions of some of these objects that the phenomenon may be more complicated than that due to simple rotation.

Two spectrograms of N. G. C. 2392 obtained with the slit passing centrally across the nebular image in position angles respectively 5° and 95° show lines of a remarkable form. The shape of the lines is similar in the two spectrograms, and their central and brighter section, corresponding to the central portion of the nebula, some 11 or 12 seconds of arc in diameter, is roughly that of a drawn bow concave toward the violet. Measures of these lines indicate a relative velocity of some 80 km./sec. for points at the ends with reference to the middle point of the bow. We do not undertake now to interpret the remarkable line form observed, but shall hope to do so later.— W. W. CAMPBELL and J. H. MOORE, *Publications Astronomical Society of the Pacific*, No. 164.

RESEARCHES ON SOLAR VORTICES.—In this connection a detailed study of the aurora, its situation, and its altitude will be of considerable interest, especially if we have auroras connected with definite sun-spot phenomena as have sometimes been observed, for it is most probable that the electric corpuscles that cause the aurora are the same as those thrown out from the sun's atmosphere; and having studied their physical properties in the aurora, we can draw corresponding conclusions for the phenomena in the sun. This connection between solar phenomena and auroras, which has been elaborated by physical methods by Professor Birkeland and mathematically by myself, will probably be of importance in future solar work. Furthermore, the photographic method of measuring the altitude of the aurora by means of two stations connected by telephone which I have employed on my expeditions in 1910 and 1913 is capable of giving very exact information regarding the auroral phenomena, thus laying a firm foundation for the conclusions we may draw from them. During the coming period of solar activity, special attention will be paid to these points of view.— CARL STÖRMER, *Astrophysical Journal*, Vol. XLIII., 1916. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

CLOSE CONJUNCTIONS OF VENUS AND JUPITER

The close conjunction of Venus and Jupiter on the evening of Sunday, February 13, had many interested observers, and was the subject of a query in the last number of the JOURNAL, which was satisfactorily answered by Mr. R. M. Motherwell, of Ottawa. In *Popular Astronomy*, for June-July, is a communication from Mr. B. H. Dawson which gives further information. He shows that in 155 years there are 158 conjunctions of Venus and Jupiter, which he further analyses as follows :—

But while there are 158 conjunctions in 155 years, there are other considerations affecting the interest of the phenomenon. First, approximately half of the conjunctions take place when the planets are morning stars, and are not noticed. Second, the inclinations of the orbit planes to each other and to the ecliptic cause the angular distance between the two bodies at conjunction to vary, sometimes being as much as eight degrees. For the conjunction to be really interesting they should pass within a degree of each other, which occurs about two-thirds of the time. For it to be striking, or as close as that of this year, they must pass within half a degree, which occurs about one-third of the time. Third, for the conjunction to be easily observable, the planets should be at least 15° from the sun with ecliptic high, as it is from December to June, or 25° with it low, as it is from June to December. If we set 20° as an average limit, we have our condition satisfied two-thirds of the time. For the interested observer the distance could be decreased to 15° and the corresponding proportion would become three-fourths. The interested observer would also avail himself of the morning conjunctions. And finally, the extreme proximity of the striking conjunctions lasts only a few hours. During this time the planets will be visible to only a part of the earth, being either below the horizon or in daylight for the remainder. The

factor arising from this cause is hard to determine, but will probably be about one-half.

Forming the continued product of the various factors for each condition, we find that about one in two of the conjunctions will be interesting, while but one in eighteen or so will be as striking as that of this year. That is, about one every other year and one every fifteen years to twenty years, respectively.

HONOR FOR DR. KLOTZ

We are pleased to learn that at the recent Commencement exercises of the University of Pittsburgh the honorary degree of Doctor of Laws was conferred upon Dr. Otto Klotz, of the Dominion Astronomical Observatory, Ottawa.

THE GREAT 72-INCH REFLECTOR

Readers of the JOURNAL will be greatly interested in the account given in this issue of the progress made in the construction of the giant reflecting telescope which will soon be in operation on Saanich Hill, near Victoria, B.C.

Before shipping the mounting of the instrument, a public exhibition of it was given on May 25 by the Warner and Swasey Co., at their works in Cleveland, Ohio. A large number of well-known scientific men and prominent residents of Cleveland inspected the great instrument, which, notwithstanding its immense weight, worked with great ease. A luncheon was given by the company at the Union Club with Dr. Plaskett as guest of honor.

ANOTHER 'RUNAWAY' STAR

Harvard *Bulletin*, No. 613, dated June 7, 1916, has the following interesting news from the Yerkes Observatory :—

From a comparison of his photographs taken with the 10-inch Bruce telescope, with the aid of the Zeiss blink-mikroskop, Professor Barnard has just discovered a star of the 11th magnitude having the remarkable annual proper motion of about 10″. The position of the star for 1916·0 is $17^h\ 53^m\ 44^s$, $+\ 4^\circ\ 27'{\cdot}4$. This star follows B.D. $+\ 4^\circ{\cdot}3560$ by $9^s{\cdot}5$ and is $0''{\cdot}4$ north. The star is shown

on several plates, one taken as far back as 1894, August 24, with the 6-inch Willard lens (at the Lick Observatory). The exact value of the motion will be published later.

The motion is confirmed by numerous Harvard photographs. The star with greatest proper motion previously discovered is known as Cordoba Zones $5^h 243$ [R.A. (1900) $5^h\ 7^m{\cdot}7$, Decl. $-44°\ 59'$], of magnitude 8·5. Its radial velocity is 242 km. per second, and taking its parallax as $0''{\cdot}32$, its velocity in space is approximately 260 km. per second. Next to this comes the star Groombridge 1830 (R.A. $11^h\ 47^m{\cdot}2$, Decl. $+38°\ 26'$) of magnitude 6·3, and with a velocity in space of approximately 250 km. per second. An interesting discussion of these 'runaway' stars is to be found in Campbell's *Stellar Motions*, p. 116 and following.

C. A. C.